INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS

PROCEEDINGS XVII CONGRESS

01-11 FEBRUARY, 1980

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MARCIANO BRION LOPEZ

and

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H

PREFACE

The XVIIth Congress of the International Society of Sugar Cane Technologists held in the Philippines from February 01 to 11, 1980 encompassed varied activities involving field trips and observations of current undertakings in the Philippine sugar industry, presentation and discussions of technical papers on sugarcane agriculture and sugar manufacture from various countries, and panel discussions on special subjects that have relevance to present day international problems like energy and sugar marketing. In their speeches, leaders cited the endeavors and contributions of sugarcane technologists to propel the world sugar industry to greater heights of development and advancement in technology.

A total of 256 technical papers comprising 183 and 73 for Agricultural and Biological Commissions and Factory Commission, respectively,were presented and discussed with their respective sectional division. Special topic on sugar based energy generation and sugar marketing and world pricing mechanism were discussed in the plenary sessions.

Manuscripts of technical papers accepted for presentation in the Congress were edited by the respective division Chairmen for pre-printing and distribution to delegates in the course of the Congress. The pre-printed materials were again edited by authors and the division Chairmen. Final editing of the manuscripts included in this Proceedings were undertaken by a group of editors from the University of the Philippines at Los Baños.

The overall aspect of editing and final printing of the Proceedings were supervised by the Committee on Publication headed by Mr. Santiago Z. Ureta with Mr. Sergio Hilado and Dr. Elpidio Rosario as members.

The discussions for the enrichment of our technical knowledge and understanding of current development in the sugar industries of the world, words of encouragement to motivate us to continue our work with more vigor and dedication and supplemental activities worthy of our remembrance were consolidated and printed in these Proceedings by the Organizing Committee of the XVIIth Congress of the International Society of Sugar Cane Technologists.

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PROGRAMME

01 February, Friday –

Registration of delegates at the Philippine International Convention Center (PICC); Other registration dates are February 02, 03 and 04.

6:30 p.m. – Welcome Cocktails at the Reception Hall, PICC

PRE-CONGRESS TOUR

02 February, Saturday –

Factory delegates' field trip for tour of: (1) Agro-Industrial Development of Silay – Saravia (AIDSISA) (2) Hawaiian – Philippine Milling Company, and (3) Victorias Milling Company, all three sugar mills in Negros Occidental.

Agricultural delegates' field trip to Canlubang Sugar Estate to see field demonstration on farm mechanization.

03 February, Sunday –

Factory delegates' field trip for tour of Central Azucarera Don Pedro, Nasugbu, Batangas

Agriculture delegates' field trip for tour of:

(1) The International Rice Research Institute (IRRI), Los Baños, Laguna

(2) The University of the Philippines at Los Baños (UPLB), Laguna

(3) The National Arts Center, Makiling, Laguna

CONGRESS

04 February, Monday –

Opening Ceremonies at the Plenary Hall, PICC starting at 10:00 a.m. with the following program:

Philippine National Anthem	–	Philippine Navy Band
Invocation	–	Monsignor Antonio Y. Fortich
Welcome to the XVII Congress of the International Society OF Sugar Cane Technologists (ISSCT)	–	Ambassador Roberto S. Benedicto General Chairman, ISSCT XVII Congress
Introduction of the Governor of the Metro Manila	–	Mrs. Julie C. Benedicto Chairperson, Ladies' Committee ISSCT XVII Congress
Welcome to Metro Manila	–	Madame Imelda Romualdez Marcos First Lady, Minister of Human Settlements and Governor of Metro Manila
Introduction of the President and Prime Minister of the Philippines	–	Ambassador Roberto S. Benedicto
Address	–	His Excellency, Ferdinand E. Marcos, President and Prime Minister
Master of Ceremonies	–	Mr. Carlos Bell Raymond

Afternoon – F r e e

05 February, Tuesday – Technical Sessions

8:45 a.m.	–	9:30 a.m.	–	General Plenary Session at the Reception Hall, PICC
		Subject	–	"High Fructose Syrups: The Competition to Sugar"

	Guest Speaker	–	Mr. Donald E. Nordlund Chairman, President and Chief Executive Officer A. E. Staley Manufacturing Co. Decatur, Illinois 62525, U.S.A.
10:45 a.m. –	4:30 p.m.	–	Presentation of technical papers by Sections at designated meeting rooms

Evening – F r e e

06 February, Wednesday – Technical Sessions

8:45 a.m. –	9:30 a.m.	–	General Plenary Session at the Reception Hall, PICC
	Subject	–	"The Politics of Sugar"
	Guest Speaker	–	Mr. William K. Miller Executive Director, International Sugar Organization (ISO) 28 Haymarket, London SWTY 4sP England
10:05 a.m. –	4:30 p.m.	–	Presentation of technical papers by Sections at designated meeting rooms
	7:00 p.m.	–	Barrio Fiesta at Folk Arts Theatre

07 February, Thursday – Technical Sessions

8:45 a.m. –	9:30 a.m.	–	General Plenary Sessions at the Reception Hall, PICC
	Subject	–	"The Use of Sugar"
	Guest Speaker	–	Mr. John M. Mount Vice-President, The Coca Cola Company, USA

P.O. Drawer 1734, Atlanta
Georgia 30301, USA

10:05 a.m. – 3:35 p.m. – Presentation of technical papers by Sections at designated meeting rooms

Evening – Free

08 February, Friday – Technical Sessions

8:45 a.m. – 9:30 - a.m. – General Plenary Session at the Reception Hall, PICC

Subject – "The Sugar Industry in a Changing Economic Climate"

Guest Speaker – Dr. Helmut Ahlfeld
Managing Director, F.O. Licht
Box 90, Ratzeburg, West Germany

Note: Dr. Helmut Ahlfeld could not attend due to difficulties with plane connections. His speech was read by Mr. Donald K. Luke, Jr., Editor of SUGAR y AZUCAR.

10:05 a.m. – 4:30 p.m. – Presentation of technical papers by Sections at designated meeting rooms

Evening – Free

09 February, Saturday – Technical Sessions

8:45 a.m. – 9:30 a.m. – General Plenary Session at the Reception Hall, PICC

Subject – "Some Economic Implications of Power Alcohol"

Speaker	–	Dr. Michael C. Bennett Deputy Managing Director Tate & Lyle Engineering, Ltd. England
10:05 a.m. – 4:00 p.m.	–	Presentation of technical papers by Sections at designated meeting rooms

Evening – Free

10 February, Sunday –

Free Day

11 February, Monday

10:00 a.m.	–	Closing Plenary Sessions at the Plenary Hall, PICC
Call to Order and Remarks	–	Ambassador Roberto S. Benedicto, General Chairman, ISSCT XVII Congress
Report of the General Secretary-Treasurer	–	Mr. Carlos Bell Raymond
Business Meeting	–	1) Report of the Chairman of the Resolutions Committee 2) Ratification of the Actions of the Administrative Committee a) The Proposed Constitution b) Fourth Meeting of the Administrative Committee (now restyled

COUNCIL) to elect 10 members to constitute the Board of Trustees.

c) The host for the XVIII Congress in 1983

d) Post-Congress Tour

Afternoon – Free

7:00 p.m. – Farewell Banquet and Ball at the Manila Hotel

12 February, Tuesday

Bon Voyage

POST CONGRESS TOUR

The Post Congress Tour scheduled to be held in Indonesia on February 12 to 19, 1980 was cancelled. The organizer of this tour, Ir. Ashardikun, Regional Vice-Chairman of Indonesia regretted that due to the limited response of participants, an organized post Congress Tour was not possible.

ADDRESS OF WELCOME

Roberto S. Benedicto
General Chairman, XVIIth Congress ISSCT

February 4, 1980

Mr. President and Madame Marcos, Distinguished Guests,
Fellow Delegates To The XVIIth Congress of The ISSCT,
And Ladies And Gentlemen:

As general chairman, and in behalf of the executive committee and the organizing committee, it is with great pleasure that I bid you all welcome to the opening ceremony of the XVIIth Congress of the International Society of Sugar Cane Technologists. We feel deeply honored that his Excellency, President Ferdinand E. Marcos, and the First Lady, Madame Imelda Romualdez-Marcos, have accepted our invitation to be with us today to open the congress. Their attendance at this opening ceremony bespeaks the importance that our government and our sugar industry attaches to this conference of sugar cane technologists who "have contributed much to an industry which is vital to the economy of our country.

We are indeed gratified that our fair City of Manila has been chosen as the venue of the XVIIth Congress and consider ourselves privileged to host the triennial meeting of this important segment of the world cane sugar industry. We are very pleased that delegates from all over the world, numbering more than 800 at the last count, have decided to participate in this congress, and we are particularly delighted that 118 of them are accompanied by their wives.

As host to the XVIIth Congress, we have invited speakers who are leaders in their respective fields to give talks on the politics and economics of sugar and the competition to sugar that is posed by the new sweetener — High Fructose Corn Syrup. This part of the programme is included for the first time in this congress in the hope that some understanding of these aspects will be of interest to the technologist and enable him to get fresh insights into other dimensions of the industry, while at the same time enlivening the daily grind of the technical meetings.

In view of the present energy crisis caused by the steadily rising costs of oil, we have, also for the first time in this congress, made arrangements for a symposium on energy. Although the manufacture of alcohol from molasses has long been ancillary to the sugar cane industry in many countries, the current crisis has given new focus on sugar cane as an alternative and renewable source of energy and should

stimulate further research in this area. We hope that the symposium will be both interesting and helpful to the technologists in this regard.

To facilitate entry in the Philippines for the XVIIth Congress the visa requirement has been waived by our President for delegates from countries which presently do not have diplomatic relations with us. The paid-up membership of the society now stands at 1988 from 76 countries. As host country, we have kept up with the publication and circulation of the NEWSLETTERS to the members since the last congress. We have received and reviewed 339 papers submitted for this congress. Of these 251 have been accepted on the recommendation of Section Chairmen and will be read at the congress. Simultaneous translation in English and Spanish will be provided at the plenary meetings, and English and Spanish at the section meetings. We have made arrangements to make your stay as pleasant and enjoyable as possible and we do hope that you will really feel at home with us. If you have visited with us before, you must have already seen something of the traditional Philippine hospitality which is rather well known. We assure the delegates that they will be received with the same friendship and hospitality whenever they can spare the time to visit with us in our homes or places of business.

The delegates who have last week visited some of our sugar cane farms, factories and experimental fields have seen a fairly representative section of our industry. would, however, endeavor to give you a brief account of its more important features , — its potentials and problems, — in order to enable you to get a fuller picture, and also to elicit suggestions during this Congress on how we may best handle some of these problems.

The cultivation of sugar cane is a very old industry in the Philippines antedating its written history which is commonly regarded to have begun when the Portuguese navigator, Ferdinand Magellan, sailing under the Spanish flag, reached the islands in 1521 on the voyage which first circumnavigated the globe. During the early part of the spanish settlement of the country which began in 1572 sugar was already an item of trade with the neighboring areas in the Asian mainland. However, it was not until the last 50 years of the spanish colonial regime which ended in 1898 that the industry developed rapidly and became the premier export product, accounting for 30 to 60 percent of the country's total exports, and achieving at that time an export record of 376,000 short tons. The outbreak of the Philippine revolution for independence, first against Spain in 1896, and then against the United States when it took possession of the Islands in 1898 as a prize of the Spanish-American war, paralized the industry and curtailed production which took many years to recover.

With the inception of free trade with the United States in 1909, the industry was modernized with the establishment of centrifugal sugar factories which replaced thousands of small and antiquated muscovado mills. The 1920's up to mid-1930's was a period of growth for the industry which was interrupted only with

the imposition of quota restrictions under the U. S. sugar act beginning in 1934. During this period the industry once more enjoyed a preeminent position in the country's economy with sugar exports rising to 63 percent of the total export trade in 1933, and posting a pre-war record crop of 1.4 million tons in 1934.

With the outbreak of the second world war and the invasion of the Philippines in December 1941 the industry ceased to operate, and after 3 years of enforced idleness was virtually totally destroyed during the ensuing struggle for liberation in 1945. It was not until 1954 or 13 years after the start of the hostilities in 1941 that the industry was able to rebuild its plant and facilities and bring production up to the level which permitted fulfilment of Philippine export quota of 980,000 short tons under the U. S. sugar act.

After the war larger factories were built while mill districts were consolidated into larger units with the resultant reduction in the number of factories to 25 from 46 before the war. These 25 post-war factories which also had a total capacity of nearly 80,000 metric tons of cane daily served the industry adequately for many years. However, as domestic consumption requirements increased and new selling opportunities developed in the U. S. market in 1960-61 it became necessary to expand the industry to meet the demand. The country with its unemployment and balance of payment problems could ill affort to pass up opportunities to augment its export income in falling to maintain production at the adequate levels.

After a few years of quota shortfalls the industry accordingly embarked on an expansion program on the encouragement of the government and with the financial support of government financing institutuions and banks. Under the program, which began in 1967, acreage increased from 282,000 hectares to 544,000 hectares or nearly twice the former area in cane within a period of 7 years, while factory capacities likewise nearly doubled from 84,000 to 186,000 metric tons of cane daily with the establishment of 17 new mills and the expansion of many of the existing mills. For the first time in its long history, the industry achieved a production level of 2 million metric tons in 1971, and in a relatively short time thereafter, almost 3 million metric tons in 1976.

As a result of the program and its timely execution, the industry was able to meet the country's export commitments during the last five years of the U. S. sugar act, and to supply fairly substantial tonnages to the world market at the time that they were sorely needed in 1974 and 1975, besides making adequate provisions for a rapidly expanding domestic market. It should be noted that the country's domestic consumption is rising at the rate of 6 percent which at this time means some 60,000 metric tons annually, — equivalent to the yearly output of a medium sized factory. In terms of employment and economic activity which have been generated by the establishment of the new factories and the opening up of new areas, the impact of the expansion program has not been inconsiderable particularly in remote localities which have heretofore not been reached by any kind of manu-

facturing industry.

It may interest you to know that all of these have been accomplished within the framework of our new society under the leadership of his Excellency, President Ferdinand E. Marcos. At no time in the past has such long strides been made in the development of our sugar industry. However, this is not unusual for our president who has a record of performance in many aspects of nation building, — particularly the socio-economy and development aspects — That is unequalled in the annals of our country. The statistics are formidable: in Building Infrastructure, — roads, bridges, school buildings, irrigation and drainage systems, powerplants, housing; in Agrarian and Social Reform; in the growth of Agriculture particularly self-sufficiency in rice which is our staple food; in the promotion of Trade and Industry, in the development of Mineral Resources; in the exploitation and development of Geothermal and other indigenous sources of energy; and so on and so forth. There are many more, But I am only a historian of our sugar industry and not of the development program of the administration and I hope I will be forgiven for straying from my subject and invading somebody else's territory which I have no intention of doing except to highlight the fact that the development of our sugar industry is but one facet of the Herculean efforts that have been and are being made in all sectors of our economy to win a measure of economic well being for our people.

The Philippine sugar industry presently consists of 42 milling districts on 6 of the country's 11 major islands. The area devoted to cane in recent years has fluctuated between 450,000 and 580,000 hectares in response to prices. Sugar cane is grown by independent farmers who mill the cane in sugar factories for an agreed share of the sugar and molasses manufactured therefrom as calculated on the basis of the weight of cane and the analysis of the first expressed juice. Participation ratios range from 60 to 70 percent for the planter and and 30 to 40 percent for the mill, with industry-wide average close to 65:35.

In crop year 1978-79 there were 31,497 planters and 34,116 farms with average farm size of 13 hectares. Fifty-three (53) percent of the farms average 2.83 hectares, while 88 percent average 5.8 hectares. Only 5.7 percent of the farms representing 41 percent of total area have areas of over 50 hectares each. Unlike many countries in latin america and africa where large mill-owned estates supply most of the cane, there are but a handful such estates in the Philippines with an aggregate area estimated at some 5 percent or less. The predominance of very small farms in our industry which are unable to absorb a satisfactory level of technology has been a limiting factor in the productivity of the industry.

Mechanization of farm operations in the industry is generally limited to land preparation in about 70 percent of the farm area. Some large farms and mill-owned estimates have mechanized all or nearly all operations including harvesting and loading but these are on relatively minor scale in terms of the total industry. Har-

vesting and loading of cane are generally done manually by migrant labor hired by contractors during the harvest season. Small-sized farms are worked entirely by animal drawn implements, while the large and medium-sized farms which are managed by progressive farmers are mechanized in varying degrees in most of the farm operations except harvesting and loading.

As a result of the continuing sugar cane variety improvement program that has been carried out for many years, local varieties bred by philsucom are almost exclusively used in the industry. These varieties have been developed for cane tonnage and sugar content as well as resistance to more prevalent diseases and have proved to be high-yielders. These varieties are now being propagated for general distribution.

Productivity in the industry vary rather widely. It is not unusual for moderately-sized farms of around 100 hectares which are efficiently and to produce 7.5 metric tons of sugar per hectare and there are many large farms that yield as high as 10 to 15 tons. On the other hand, we have the extremely low yields obtained in a large number of very small and sub-marginal farms which range from 2.5 to 3.5 tons.The industry average is thus pulled down to around 5 to 5.5 tons.

On the basis of total factory capacity of 187,000 metric tons of cane daily for the existing 42 factories, annual production capacity of the industry is estimated at 3.7 million metric tons, raw value. In crop year 1978-79 production has declined to 2.37 million tons. Due to very low world prices the industry had thus operated at only 64 percent of factory capacity that year. Very recently 3 refineries have been established with a daily capacity of 500 metric tons each. These bring the total refinery capacity in the country to about 1.0 million tonnes yearly and will enable exportation of refined sugar from the country in the near future. Our industry, despite its problems, would thus be in a position to help supply the world's growing need for sugar more than it is presently able to do if the price is right.

Thank you,

ADDRESS

By Imelda Romualdez-Marcos
Governor of Metropolitan Manila

At The Opening Of The XVIIth Congress Of The International Society Of Sugar Cane Technologists

February 4, 1980

Mr. President, Mr. Chairman,
Distinguished Guests and Delegates,
Ladies And Gentlemen:

On behalf of the Commission and the People of Metropolitan Manila, I wish to add to the words of welcome already expressed by the Chairman, my profound appreciation for the honor you have bestowed upon us in meeting here in our Capital City for the XVIIth Congress of the International Society of Sugar Cane Technologists.

In the last three years since the inauguration of the Philippine International Convention Center our city has been privileged to host a wide array of International Conferences of World Organizations including man of the specialized agencies of the United Nations. However, this is the first time that we have had the pleasure of hosting a Conference of sugar men with whom we feel the greatest affinity because of the very important role that the sugar industry plays in the life and economy of our people.

The Philippines is a natural producer of sugar cane. It is grown in nearly all parts of the Islands from the Southernmost Province of Davao to the Northernmost Province of Cagayan. And it is grown not only around large sugar Factories but also in remote localities where we still have hundreds of small animal-driven mills producing the crude muscovado sugar which is preferred by many of our people, particularly in rural communities.

When I think of the industry, I see it not only in terms of its export earnings and other benefits that it confers on our economy which undoubtedly are of vital importance to our existence but even more so in terms of the thousands of our workers in the fields and factories who depend upon it for their livelihood. According to statistics, there are some 580,000 persons who are employed in the industry while there are more than 5 million or eleven percent of the population who are directly or indirectly dependent upon it. This makes the sugar industry one of the largest employers of labor in the country and is consequently a critical factor in

its socio-economic stability.

That is why we share a common concern with you, the sugar technologists, in raising the level of productivity of the industry in order to better enable it withstand the rigors of a generally unstable and depressed world sugar market. With high yielding varieties of sugar cane which have been developed in our experiment stations, many of our medium sized farms have been able to maintain yields at levels comparable to those obtained by some of the more efficient producers in other countries. Our problem lies in the large number of marginal and sub-marginal farms of less than 1 hectare to a few hectares which are unable to utilize known and improved methods of production.

At any event there are not very many in the industry, if at all, who can produce sugar at such a low cost as to permit it export sale at 7 or 8 cents per pound which has prevailed in the world market in the last three years. We are told that these very low prices have been due mainly to dumping of heavily subsidized beet sugar by western european countries. If so, I am afraid that even the most efficient system of sugar cane production that can be developed by the technologists would in the long run be of little avail. It is regrettable that the resources of rich and highly industrialized countries should be used to destroy the sugar cane industry of poor developing countries like ours which depend on a few agricultural products for its survival. And it is indeed ironic that some of these countries which had supplied us with machineries and equipment to set up our sugar factories have turned around to make it virtually impossible for us to operate them at any profit.

Presently, we are enjoying good price in the world market but how long will it last? We can only dare hope that through the instrumentality of the international sugar agreement, stability in the world market will be achieved to a degree that will make it possible for the sugar industry to make sustained progress towards the orderly fulfillment of the world's demand for sugar in the years ahead. To help achieve this objective, we in the Philippines have cooperated fully in the observance of the agreement although this has for us meant curtailment of production to less than two-thirds of the industry's capacity. However, as nothing less than concerted effort by all members is needed to ensure its effectiveness, it behooves all to give it its fullest support and to comply faithfully with all its mandates to the end that the benefits accruing therefrom in terms of stability of the market and reasonably remunerative prices shall redound to the benefit of all, consumers and producers alike.

Although big strides have been made in recent years towards industrialization, the Philippine economy remains basically agricultural in character up to this stage. Export trade, which is perennially on the deficit side, principally consists of coconut products, forest products, sugar, mineral products, bananas, and non-traditional exports which includes several items of manufacture. Until 1977 sugar, which accounts for roughly 20 percent of total export receipts, has vied with the coconut

products for the first position in the export list. However, due to the sharp decline in volume and value, sugar receipts has dropped to the lowest position except bananas. Rice which is our staple food, and by far the country's largest agricultural crop, has been imported almost yearly to fill local production shortages until 1972. In that year self efficiency in this food was achieved after several years of massive rice production campaign. In 1977 the country became a net exporter of rice for the first time, and we have since been exporting this commodity in increasing quantities. Notwithstanding the growth of our export trade, we have consistently posted trade deficits which have ran up to well above 1 billion U. S. dollars in recent years, due in particular to imports of crude oil. The sharp decline in export income of sugar has obviously been a factor of major importance in widening the country's trade gap in recent years.

In conclusion, may I express the hope that your XVIIth Congress will be a creative process for the world sugar cane industry and that your stay in Manila will be a memorable and pleasant one.

Thank you

Address by the Honourable President & Prime Minister of the Philippines, on the occasion of the 17th Congress of the International Societ of Sugar Cane Technologist on February 4, 1980

Mr. Chairman, Madame Marcos,
Distinguished Guests and Delegates,
Ladies and Gentlemen:

It is indeed my great pleasure to be with you at this opening of the XVIIth Congress of the International Society of Sugar Cane Technologists and to welcome the Delegates and their Guests on behalf of the Government and the people of the Philippines.

In convening here in Manila for its 17th Congress, the International Society of Sugarcane Technologists brings this important forum to a part of the world in which sugar for several centuries now has been a central part of national vitality and progress.

In behalf of the people and government of the Philippines, I would like to thank the Society for according us this privilege, and to tender you the hospitality of our country.

As the 6th largest producer and 4th largest exporter of sugarcane in the world, we in the Philippines attach great importance to the work of the International Society of Sugarcane Technologists, and we share the high hopes of many for the success of your deliberations.

In all the years since the Society was first founded and convened its very first International Congress, the work of Sugarcane Technologists has always stood prominently as a force for vitality, efficiency and productivity in the world sugar industry. Today, more than ever, we look to your field of specialization for continued vigor and vision in the support of an industry which in recent years has known severe difficulties.

It is surely ironic and significant that in a world beset by growing food shortages and all forms of scarcity, we find our problems in the sugar industry to be rooted in abundance, or even super abundance while we strive in other areas to produce more in order to feed the world, we find ourselves in this sphere constrained as it were to temper the tremendous productivity of our industry.

This says something about the inadequacies of our global system. But even more, this is convincing proof of the capability of the sugar industry and this is the

measure of the tremendous advances made by sugarcane technology over the years.

So I should like first of all to pay tribute here to the Society and to Sugarcane Technologists all over the world for their exemplary contribution to the sugar industry. We especially single out for mention here the spirit of cooperation in technical research and the free exchange of technical information which the Society has fostered among sugar producers, and which has formed so great a part of the surge in productivity throughout the sugar-producing nations.

In this tremendous technological feat, we also read the promise of a better future for the industry. Many of us look today to the continued advances in sugarcane technology as an essential factor in building greater stability and profitability in the world sugar industry. For while our problems may seem to arise from the instabilities of global trade, we know and we recognize that long-term stability will depend on the success of efforts now being undertaken to maximize efficiency in sugar production and to reduce production costs to levels that will assure profitable prices even in the midst of abundance.

As the world moves closer towards rectifying the problems engendered by the past and towards implementing the terms of the International Sugar Agreement of 1977, we will witness improvement in world prices of sugar. Yet the fact will remain, that given better mechanisms for trade, there is no substitute for efficiency and productivity in the industry, no alternative to the effective utilization of resources, in attaining growth and stability in sugar.

The experience of the Philippine sugar industry is revealing of both the problems and the prospects of the world sugar industry. And I hope you will permit me to speak of that experience in keynoting the themes of this congress.

The sugar industry occupies a prominent position in the economy of the Philippines. As the country's oldest export industry, it has provided livelihood for large segments of the population from very early times. Towards the later part of the last century, and again in the 1920's to mid-1920's, the industry was the main pillar of the national economy, with sugar constituting up to 60 percent of our total export trade. The rapid growth of the industry during these periods might have led to the development of a one-crop economy in the country but for the protracted interruption caused by the Philippine Revolution for Independence in 1896 which lasted up to 1901, and subsequently, by operation of the Philippine Independence Act and the U.S. Sugar Act which limited the entry of duty-free sugar into the United States beginning in 1934.

While political events appear to have thus conspired, perhaps providentially, to prevent our heavy dependence on a sugar-based economy, the Philippine Sugar Industry nevertheless remained an importance element in the economic progress

of the country. Despite the quota restrictions under the U.S. Sugar Act, the industry provided a relatively stable source of export income equivalent to an average of over 20 percent of total export receipts during the 40-year period that the act was in force, excepting for the war years and the post-war reconstruction period. It is indeed regrettable that such a finely-tooled piece of sugar legislation as the U.S. Sugar Act, which has worked well under all but the most unusual circumstances, should be permitted to die.

Since the expiration of the Sugar Act in 1974, the Philippines has become part of the world free market. As member of the International Sugar Organization we have participated in the U.N. Sugar Conferences of 1973 and 1977 and cooperated in the international efforts to negotiate an agreement with economic clauses so as to achieve a measure of order and stability in the world market. These efforts culminated in the successful conclusion of the International Sugar Agreement of 1977, and we in the Philippines would like to believe that we have helped make this possible by sacrificing 100,000 tons of our own basic export tonnage to break the deadlock on quota levels which had continued to be disputed up to the closing day of the conference.

When the agreement entered into force on January 1, 1978, we had hoped that world prices which had dipped to as low as 6.11 cents in 1977, would soon improve. However, it took much longer time than expected for the agreement to take hold. In the first twenty months the agreement entered into force, the monthly average of ISA daily prices fluctuated between 6.4 cents and 8.6 which are way below the costs of the world's most efficient producers.

As a result of extremely low prices and greatly reduced volume, our export income from sugar in 1977 and 1978 declined for the first time in a peacetime year to less than one third of the normal level. For a small developing country with limited resources like ours, the effect of such an extreme reduction of income on our economy, which is already reeling from the impact of constantly escalating oil prices, has been predictably severe due to price constraints, large areas went to other and more profitable crops which production dropped sharply to 2.3 million tons in the last two years from 3.0 million tons in 1975-76. At this reduced production level the industry has operated at less than two-thirds of capacity.

After more than three long years of disaster prices, the world market begun to pick up last October, reaching 11 cents, which is the minimum price of the ISA price range, for the first time under the agreement in October 22. Since then the ISA prevailing price has advanced to 15.73 as of January 18 while the ISA daily price was 17.96 cents as of the same date. If this trend continues we may have 20 cents sugar before long.

It appears that the price advance has been fueled by a decline in production which is attributed to adverse weather, low prices and quota limitations on exports

under the agreement. World production for crop year 1979-80 is currently estimated at 86.6 to 87.7 million tons as against consumption estimate of 90.6 to 91.6 million tons which leaves a deficit of 4 million tons. However, this does not mean that a shortage of this size actually impends. It only means that carryover stocks from last year which stood at some 30,000 tons or 33 percent of yearly consumption, will be drawn down by this year's deficit to 26,000 tons, equivalent to 29 percent of consumption. In effect world supplies will be tighter and therefore prices should be higher. However, the statistical picture does not suggest a price explosion which is triggered only when stocks go down to 24 percent according to statisticians.

That, we believe, is for the best since, as everyone knows, the familiar "boom-and-bust" cycle of the industry is not in its own interest, nor that of the consumers, and should therefore be avoided if possible. Perhaps more than anything else, the industry needs a climate of stability under which it can progress and grow in a manner which would enable it to meet the rising world demand for this important food. The mechanism for achieving this stability already exists in the International Sugar Agreement of 1977 which is now beginning to show its usefulness in this regard, and therefore all possible and necessary means should be availed of by the world sugar community to strengthen it and preserve its integrity.

One aspect of our sugar industry that bears repeating is the fact that the administrative supervision and control of the industry has since July 1977 been consolidated and vested in one government agency, the Philippine Sugar Commission, in order to promote the stabilization and integrated development of the industry. The commission formulates and implements government policies affecting all phases of the industry. As the single selling agency for sugar, it buys and sells all sugar for export as well as domestic distribution at prices which would assure fair returns to the producer. Moreover, it is empowered to organize sugar planters cooperatives and to assume control and supervision of mills and refineries which are unable to meet their financial obligations or which may have become inefficient in their operation.

Since the establishment of the commission two and a half years ago, it is significant that it has taken a number of initiatives in fulfillment of its mission. Among these were:

1. The establishment of the Republic Planters Bank to Provide for the financing needs of the farmers for the production of the sugar crop at minimum interest rate which has since been fixed at 10 percent;

2. The establishment of the National Sugar Trading Corporation to handle the merchandising of sugar in the domestic and export markets;

3. The acquisition and operation of the Guimaras Bulk Sugar Installation, the Visayan Stevedoring Transport Company and the Panay Railways to secure

economies of scale in the transportation of sugar and sugarcane and the bulk storage and handling of sugar for export;

4. The establishment of 3 new refineries with refined sugar capacity of 500 metric tons each to meet increasing demands of the domestic market and enable the industry to fill contracts for refined sugar for export markets; and

5. The management and operation of two 4,000-ton sugar factories in order to help develop sources for cane supply and enable them to operate efficiently at capacity. All of these initiatives and endeavors have been undertaken by the commission in addition to other functions connected with research, field extension service, administration, and others, for the very same purpose that engages the attention and energies of the sugar technologist in the performance of his assigned task in the sugar industry, and that is to maximize efficiency and reduce costs in the industry.

The point of all this is that we in the Philippines have had to adopt a strategy that not only places its faith in high prices in the world market, but more importantly seeks to improve our total institutional capacity for the efficient production of sugar. In sum, we have had to rationalize national sugar production; we have strengthened the industry in areas where it needed utmost support; and we have sought to eliminate waste and inefficiency from production to milling to the export of the commodity.

Thus, we have great faith that as world trading conditions firmly stabilize and improve, our industry and our country will be in a position to benefit from it not just for one planting season but for a good long period to come.

I believe that much the same is taking place in other sugar-producing countries, and in the global industry as a whole. Everyone distrusts now the old capricious turns in world sugar demand and prices. Everyone wouldn't mind not experiencing anymore the boom market conditions of earlier years as long as they can avoid the disaster years of bust prices. Everyone wants a climate of stability in which the highly-advanced technology of sugar production can fully work for the benefit of all, and can fully progress to open new possibilities for the world sugar industry.

Reflecting on the past several years of the industry we must surely conclude that it has not been an easy one for the world sugar community.

But addressing ourselves to the future, it seems to me auspicious that we begin the new decade with salutary developments engendered at last by our stabilization efforts. And it is on this note that I would close with the prayer that the decade will smile benignly on the determined efforts of the world sugar industry to improve its position and its future, and that you in this Society will continue to spearhead technological advances in this vital industry.

Thank you and good day.

PLENARY SESSIONS

International Society of Sugar Cane Technologists
Manila, Philippines . February, 1980

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—Ed.

High Fructose: The Competition to Sugar

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It is an honor to be the first representative of the corn sweetener industry to appear before a Congress of the International Society of Sugar Cane Technologists. This is a recognition that new dimension has been added to the sweetener world, high-fructose corn syrup (HFCS). High-fructose corn syrups do, indeed, compete with sucrose, especially in the United States. However, this competitive relationship makes companions of corn sweetener producers and sugar refiners, and these companions have similar opportunities and challenges. Everyday, work is done with two of the world's greatest agricultural resources, sugar cane and corn, two renewable resources with untapped potential.

To appreciate fully the economics of high-fructose corn syrups, one must understand that the corn-refining process extracts several valuable co-products, starch, corn oil and corn feeds. Due to the nature of the process, the production of these products is interrelated, and the market value of the corn oil and corn feeds has a direct bearing on the cost structure of high-fructose corn syrups.

In recent years, the demand for corn oil and corn feeds has been extremely strong, and, consequently, by-product recovery has ranged from 50 to 70 percent of the per-bushel corn cost. Obviously, this has had a favorable impact on the economics of all corn sweeteners. These are no present indications that these by-product values will change substantially in the near future Demand for corn oil remains strong, and corn feeds continue to be a key protien source in poultry and livestock rations.

Turning specifically to HFCS, the concept of converting glucose to fructose is not new. Initial attempts at alkali conversion date back to 1895.

It was not until 1957, however, that the first attempt at enzymatic conversion appeared. In that year, a patent was issued to Marshall and Kooi of CPC International for work with xylose isomerase to isomerize glucose to fructose. In the mid-1960's, Takasaki of the Japan Fermentation Research Institute discovered the first practical organisms, streptomyces, for the enzymatic conversion of glucose to fructose. Commercial development of high-fructose corn syrup in the United States, based upon Takasaki's work, was carried out by the Clinton Division of Standard Brands, Inc., in the late 1960's.

By 1972, two U.S. companies, with a combined annual capacity of approximately 425 million pounds (191.250 tonnes) comprised the entire industry capability for producing high-fructose corn syrup. Please note that all volumes in this article are presented on a dry basis, as opposed to a liquid or commercial basis.[1] The extraordinary circumstances of 1974-1975 in the sugar world caused the formative years of high-fructose corn syrup to be compressed into an abnormally short time frame. The results have been both positive and negative. The sugar price spiral of 1974-1975 helped establish HFCS as a nutritive sweetener, but it also created a major problem for the industry — overcapacity.

Since 1972, some 4.6 billion pounds (2,070,000 tonnes) of capacity have been added by the U.S. corn refining industry. In essence, 15 to 20 years of normal growth have been compressed into a much shorter time frame. Overcapacity, coupled with depressed sugar prices, has led to unattractive returns on investment over the last few years. This condition has slowed further expansion and, as a result, supply and demand in the U.S. are beginning to move toward equilibrium.

Fortunately for the U.S. industry, the markets for high-fructose corn syrup have developed at a good rate. Sales of the standard 42-percent syrup have increased nearly sevenfold since 1972. In addition, a "second generation" 55-percent fructose syrup became a commercial product in 1978. Sales of HFCS in the U.S. in 1979 are estimated at approximately 3.6 billion pounds (1,620,000 tonnes). This represents a volume gain of 30 percent over 1978, with a large portion of the increase attributable to the 55-percent product.

More important than a history, perhaps, would be a forecast of the potential of HFCS for further replacement of sugar in the U.S. Sales of HFCS will continue to grow in the U.S. market, but not as dramatically as in the past. This year (1980), the U.S. corn refining industry is expected to sell about 4.1 billion pounds (1,845,000 tonnes). Of this total, it is estimated that 2.9 billion pounds will be the 42-percent syrup. Essentially all of the remaining 1.2 billion pounds will be the 55-percent product, with very limited sales of 90-percent fructose. From these figures, it is obvious that sales of the 55-percent HFCS are expected to increase substantially — in fact, by more than 50 percent over 1979. The 42-percent syrup will enjoy much more modest growth.

The 55 percent HFCS is the result of new fractionation technology,

[1] *The 42 percent fructose corn syrup is usually sold at 71 percent solids and the 55 percent high fructose corn syrup at 77 percent solids.*

involving the chromatographic separation of fructose from dextrose by means of ion-exchange resins. Enzymatic conversion of dextrose to fructose reaches equilibrium at 50-percent conversion and, therefore, the original high-fructose corn syrup contains 42-percent fructose as the commercially practical limit. By using the fractionation technology fructose-bearing syrups of up to 100 percent can theoretically be produced. But, to date, only the 55-percent and 90-percent products are commercial realities.

In taste tests of comparable fructose/water solutions, the 55-percent syrup is judged to be about 10 percent sweeter than the 42-percent product, and this difference generally holds true in most applications. In addition to greater sweetness, the 55-percent syrup has slightly solids, lower dextrose content and a more favorable polysaccharide profile. In total, these characteristics have permitted the 55-percent syrup to compete successfully as a match for medium invert sugar, the most popular sweetener with the U.S. soft drink industry. The success of the 55-percent HFCS makes the near-term outlook for high-fructose corn syrup positive in the United States. Sales of the 55-percent product are expected to more than triple by 1983.

In the same time frame, a growth rate of only three to four percent per year is projected for the 42-percent syrup, with a relatively mature picture thereafter. Reflecting this slowdown, future expansion of the U.S. fructose industry is anticipated to be more measured than in previous years. One must consider that the euphoria associated with high-fructose syrups in the mid-1970's has been replaced by realism. Producers and users are now fully aware that HFCS is a product of quality and economic advantage, but it also has limitations. A review of the U.S. sweetener market by segments will verify this statement.

Sugar usage in baked goods, cereals and some allied products, amounted to 2.5 billion pounds (1,125,000 tonnes) in the U.S. in 1979. HFCS accounted for an additional 670 million pounds (301,500 tonnes), or 21 percent of the sweetener usage. It should be noted, however, that because of price relationships that have existed, much of the HFCS growth in this market category has been at the expense of other corn sweeteners, dextrose in particular. High-fructose syrup has the potential to gain a 25-percent share in this market segment. Further growth will be prevented by the product's lack of ability to crystallize, coupled with hygroscopic (moisture absorbing) and browning tendencies.

In confections, where 1.8 billion pounds, (810,000 tonnes) of sugar were used in 1979, HFCS accounted for less than one percent of the sweetener total. HFCS usage likely will remain low in this category, since the economics favor continued use of regular corn syrups in combination with sugar. Again, lack of crystalline structure and moisture affinity also will limit use of HFCS in candy. Sugar usage in U.S. dairy products totalled 1 billion pounds (450,000 tonnes) in 1978, with high-fructose syrups adding another 320 million pounds (144,000 tonnes). HFCS usage could increase to slightly more than 30 percent in this category, with its growth being limited by its tendency to lower the

freezing point of products like ice cream.

The U.S. beverage industry consumed 5.3 billion pounds (2,385,000 tonnes) of sugar in 1979. In the same year, this industry used HFCS for 24 percent of its sweetener needs, or 1.7 billion pounds (765,000 tonnes). In this particular market, the potential for high-fructose syrups is considerable. High-fructose syrup could achieve 90 percent of the total if Coca-Cola and Pepsi-Cola eventually approve its use as a total sugar replacement in their colas. Recently, The Coca-Cola Company approved the 55-percent HFCS at a 50 percent sugar replacement level in Coke. This is a major breakthrough for HFCS and leaves the industry short of capacity in the 55-percent product. It should be noted, however, that over-capacity still exists for the 42-percent syrup.

In canned goods, where sugar usage in 1979 was 1.1 billion pounds (495,000 tonnes), high-fructose syrup use amounted to 765 million pounds (303,750 tonnes). HFCS has the potential to displace additional sugar in canned goods, but its browning characteristics will be a growth inhibitor. Some 1 billion pounds (450,000 tonnes) of sugar were utilized in other U.S. processed foods in 1979. In these same foods, which include jams and jellies and catsup, 200 million pounds (90,000 tonnes) of high-fructose syrup also were used. Inasmuch as high fructose is hygroscopic and not economically available in dry form, its future will be limited in this category to 25 to 30 percent sugar replacement.

These statistics and projections emphasize that sugar is, and will remain, the sweetener standard of the United States and, most certainly, the world.

Another reason for projecting slower growth of the U.S. industry is the dramatic increase in capital required to build or expand production facilities. For example, a 400-million-pounds-per-year plant cost $50 million to construct in 1972; the same facility today would require a capital expenditure of $125 million, 2.5 times greater than eight years ago. The high-fructose syrup industry not only is capital intensive, but its economics are influenced by a number of other important factors, including operating rates and the cost of raw materials, energy, enzymes and labor.

Researchers at Purdue University, in West Lafayette, Indiana, USA, recently completed a study[2] of the current economics of producing high-fructose corn syrup, taking into account these key variables. Not all data in the study are totally accurate, especially the capital estimates, but the report's conclusions are representative of the experience of U.S. high- fructose corn syrup producers.

U.S. producers do not release their cost-of-production figures. It can

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[2] *Department of Agricultural Economics,* Cost of Producing High Fructose Corn Syrup: An Economic Engineering Analysis, *Station Bulletin No. 239 (Purdue University, West Lafayette, Ind., USA: Agricultural Experiment Station, Sept. 1979).*

be assumed, however, that present costs (excluding cost of capital) range from $0.08 to $0.12 per pound for the 42-percent fructose syrup, depending upon the size of plant and the operating rate. Production costs for 55-percent HFCS usually run 15 to 25 percent higher. The operating rate has a significant impact on the cost of producing high-fructose syrup. Because of its capital intensity and high fixed charges, the corn-refining industry tries to operate at above 90 percent of engineered capacity for at least 330 days a year. Published data suggest that a one percent adjustment in operating rates from the 90 percent level changes production costs by one-half percent per pound of high-fructose syrup, a reasonable finding.

The cost of corn is the largest single element in the cost of producing high-fructose corn syrup and accounts for approximately one-half of the total. It is therefore the most influential variable cost factor in high-fructose syrup production. An industry rule-of-thumb is that a $0.50 reduction in the price of corn equates to a $0.01-per-pound improvement in the cost of producing high-fructose corn syrup, all other factors being equal.

Enzyme costs in producing high-fructose syrups have been reduced significantly through improved enzyme technology. Today, enzymes account for five percent of the total cost of producing fructose, compared to 16 percent in 1972. Many organisms have been patented as isomerase producers, possibly as many as 100. For commercial purposes, however, there are five widely used systems today. Each utilizes a different organism, a different immobilization method and has different properties.

Enzyme suppliers have greatly improved the production of glucose isomerase since the early 1970's. None of the leading suppliers have published data, but undoubtedly yields have risen, perhaps by 10 times or more. As a result of this advance and greater competition among enzyme suppliers, the selling price of glucose isomerase has been relatively constant for the past four years.

Immobilization techniques employed by enzyme producers also have advanced. New carriers and immobilization methods have reduced losses and improved the economics for enzyme manufacturers. These new immobilized enzymes have higher isomerizing activities; they are less compressible and more permeable, permitting higher flow rates and better conversion efficiencies. The high-fructose syrup industry also has learned to use its enzymes more effectively, maximizing the productivity of fructose syrup per pound of enzyme.

Details have not been released by producers, but patent literature suggests that enzyme life and productivity can be extended by careful control of isomerization conditions (such as pH and temperature), the removal of trace metals (such as calcium and copper) and the use of selected additives. The end result has been a steady reduction in enzyme costs. In the mid-1970's, enzyme suppliers talked about a guaranteed cost of about $0.75 per hundredweight of high-fructose corn syrup, on a dry basis. Today, the figure is closer to $0.40 per hundredweight and many U.S. fructose producers have even better experience.

While much progress has occurred in enzyme technology, there is additional room for improvement and a further lowering of costs. At this stage, however, most scientists believe another breakthrough may be required in enzyme genetics or in the discovery of more heat-stable varieties before major additional savings can be achieved.

The newest technology to emerge in the corn-refining industry, of course, is the fractionation of fructose and dextrose to achieve the higher or "second-generation" fructose syrups. Initial fractionation processes of three years ago utilized small-scale batch methods. In a short time, the state-of-the-art has evolved into large-scale continuous systems. Several have been commercialized and dramatic improvements in process efficiency and product quality are being reported. Once again, fructose producers have not released scientific information. It can be assumed, however, that product recovery with the new continuous fractionation has been raised by 10 to 15 percent and water usage cut in half, as compared to results of early batch techniques.

One of the more worrisome elements in corn refining and high-fructose syrup production is the escalating cost of energy, which is equally troublesome for the cane sugar industry. In terms of high-fructose syrup production costs, energy has risen to nearly 15 percent of the total, quadrupling in the past six years. Corn refiners, especially in the newer plants, are combating the rising cost of energy by employing such devices as mechanical-recompression evaporators and heat exchangers. By utilizing such technology, a corn-refining plant today can be as much as 30 to 35 percent more energy efficient than 10 years ago. At best, however, this is only a holding action against rising energy costs.

A fifth cost factor in producing high-fructose syrup is labor, which accounts for approximately 10 percent of total operating expense. Again, high-fructose syrup producers have made significant strides in lowering man-hours per hundredweight of finished product. As new high-fructose syrup plants are constructed and existing ones expanded, labor-saving features will become increasingly commonplace.

One can conclude that the future is promising for high-fructose corn syrup in the United States. It is not without its problems and limitations, but it continues to evolve in a positive manner.

Elsewhere in the world, the picture is less dynamic. Next year, HFCS will account for only 2.5 percent of the total world sweetener consumption; in 1985, this figure is expected to rise to just over 3.0 percent. The product's growth will continue to be concentrated in major developed countries, having minimal impact on the world market as a whole.

The passage of time has proved many of the early predictions for rapid world-wide growth of high-fructose syrups to be baseless. It also has served to clarify the circumstances necessary for a high-fructose syrup industry to thrive. First, it appears that the producing nation must be a net sugar importer. There also must be substantial consumption of liquid sugar through a well-

developed processed food and beverage industry. An abundant starch supply must be available. Maize, grain sorghum, wheat, white and sweet potatoes and manioc all are good carbohydrate (starch) sources. In most regions of the world, however, these are more valuable as carbohydrates in the diet than as the raw material for fructose.

There are other considerations, such as a labor force trainable in the operation of sophisticated processing equipment; an ample fresh water supply and fuel source; access to processing chemicals and enzymes; and, of course, availability of the considerable capital required to build a fructose facility of sensible scale. A final requirement is a transportation and distribution system advanced enough to handle the special shipping and storage needs of fructose sweeteners, and their co-products (such as corn oil and corn feeds in the case where corn is the raw material). In all, these factors limit the potential of fructose technology to a few of the more industrialized nations, at least for the foreseeable future.

Estimates of sweetener consumption in the highly developed nations place high-fructose corn syrup at 10 to 12 percent of the total usage by 1985.[3] In addition to the United States, only two other areas of the world have developed fructose industries to any marked degree. They are the European Economic Community and Japan. There are many similarities between the fructose industries of the U.S. and Japan, in terms of accomplishments and difficulties. Sugar consumption in Japan increased by two percent for the twelve months ended September, 1979. During the same period, high-fructose sugar consumption increased by 10 percent, for a total gain of 50 percent since 1976-1977. High-fructose syrup now accounts for approximately 10 percent of the total Japanese sweetener market, compared to five percent in 1976-1977.[4]

Nevertheless, high-fructose syrup sales have not met the more optimistic projections. Japanese producers have shared a common malady with their American counterparts—overcapacity. Despite overcapacity, several producers have continued to expand, particularly for second-generation products. Expansion of the 55-percent syrup, undoubtedly, is in anticipation of greater use of the product by the Japanese soft drink industry.

Government policy has been a major force in shaping the progress of HFCS in the European Economic Community (E.E.C.) High-fructose syrup, or isoglucose, as it is more commonly referred to in Europe, emerged in the mid - 1970's in the E.E.C. The reception of the new sweetener was aided by the fact that the beet sugar industry was protected by a quota system, elevating the price of sugar as much as 30 percent over the world price to European food and beverage producers. In 1976, approximately 160 million pounds (72,000 tonnes) of high-fructose syrup were sold in the E.E.C. and market projections were calling for 600 to 900 million pounds (270,000 to 405,000 tonnes) in 1978. Longer-range forecasts in excess of 2 billion pounds (900,000

[3] *F.O. Licht,* Industrial Sugar Report *(April 1978);* FAO Commodity Review and Outlook, 1977.
[4] *F.O. Licht,* Daily Sugar Information Service, *(Oct. 12, 1979).*

tonnes were discussed.

Already faced with a beet sugar surplus, the E.E.C. took several steps to curtail the growth of HFCS, including a production levy. In total, the actions seriously affected the economics of HFCS in the Common Market, and several European corn-refining companies initiated legal proceedings. In October, 1978, the European Court of Justice determined that the production levy was discriminatory. Last year, however, the E.E.C. Council of Ministries approved a new plan regulating the growth of high-fructose syrup by means of a minimum/maximum quota system. Under this new plan, producers must pay a levy on any fructose syrup produced above their minimum quotas and not exceeding the maximum quotas. High-fructose syrups produced above the maximum quotas cannot be marketed in the E.E.C.

It would appear that such measures will slow the progress of high-fructose syrup in the Common Market. At the present time, high-fructose producers are operating at levels of production and profitability that might best be described as discouraging. Moreover, their future remains clouded.

There are HFCS developments in other parts of the world, including Souht Korea, Argentina, Spain, Canada and Eastern Europe, but none are on the scale of those in the E.E.C., Japan and the U.S.

In examining the world outlook for high-fructose syrup, one must keep in mind that the production of cane sugar in tropical regions is the most efficient sweetener system in the world, in terms of solar conversion and its unique ability to use a by-product as a fuel source. Thus, through the next decade it appears that the impact of high-fructose corn syrup on the international sugar cane industry will be negligible.

Your author noted earlier that both corn refiners and sugar processors share a similarity in their work with vital renewable resources. The world's energy crisis has underlined the growing importance of renewable resources and added a new dimension to the work done by both parties. The graphic evidence lies in the mutual interest of both industries in the production of ethanol as a fuel. No review of high-fructose syrup, therefore, would be complete without giving brief consideration to the implications of ethanol production on the U.S. corn refining industry.

In the U.S., the synthetic fuels program covers a number of alternatives, such as coal liquids and gases, shale oil and other unconventional sources But most experts agree that ethanol has the most immediate potential. There are, of course, several agricultural raw materials available in the U.S. from which to make ethanol, including sugar, corn, grain sorghum and potatoes. Corn and grain sorghum are considered the most attractive feed stocks in terms of availability and economics. The U.S. corn-refining industry, therefore, is ideally positioned to become an efficient ethanol producer.

To date, the U.S. government's encouragement to corn refiners for ethanol

development has been confined to motor fuel extenders. It has consisted primarily of the exemption of motor fuels from a $0.04-per-gallon federal tax, if they contain ethanol made from agricultural raw materials. A number of additional incentives are being proposed to encourage greater production of ethanol. These include a permanent waiver of the federal excise tax and additional investment tax credits, loans, grants and loan guarantees for the construction of ethanol plants.

The government believes these incentives can significantly increase production of fuel ethanol from the current level of approximately 60 million gallons (227 million liters) per year. Government officials apparently are not in total agreement as to a reasonable goal for ethanol production. Public statements have ranged from 300 to 900 million gallons (1,137 to 3,411 liters) annually by 1982.

World events have given added impetus to the ethanol program in the U.S. Recently, the government announced a program to stimulate production of ethanol from corn displaced by the U.S. embargo of grain to Russia. A goal of 500 million gallons (1,895 liters) by next year was mentioned.

Whether any one of these projections becomes a reality remains to be seen, but one thing is undeniable. The development of ethanol as a fuel in the U.S. will affect the future of HFCS. From a positive view, a number of U.S. corn refiners now have completed feasibility studies regarding the diversion of existing processing capacity to the production of ethanol. As much as 100,000 bushels of daily corn processing capacity conceivably could be switched from corn sweetener production to ethanol. Should this occur, the supply-and-demand picture for corn sweeteners would be changed dramatically.

On the other hand, a major building program in terms of new facilities and the expansion of existing ones would be required if the government's goals of greater ethanol production are to be achieved. Large additions of new corn-processing capacity to produce ethanol will result also in large increases in corn feeds and corn oil. This, in turn, raises the difficult question as to what price level might be required for these additional by-products to be absorbed in the marketplace.

A rapid expansion of corn-refining capacity for ethanol production would probably raise the cost of corn and substantially lower by-product credits, making it more difficult for high-fructose syrup to maintain its traditional cost differential to sugar Expansion of U.S. corn refining facilities for ethanol also raises the longer-term specter of overcapacity, should government policy toward fuel alcohol change at a future date. A shift in government policy could depress the ethanol market, with a result that corn refiners might be forced to operate their plants for startch or add finishing capacity for corn sweetener production, depressing margins for both products.

At this point, it appears U.S. corn refiners have not made a final decision on the amount they will commit to the production of ethanol, but clearly

the future of high-fructose syrup is interrelated with ethanol in the U.S., as is sugar on an international level. The concept of ethanol fuel from sugar cane and corn is a common denominator for those industries. Of greater importance, it symbolizes the untapped values within the raw materials and may well be the first step in a global movement toward fuller utilization of the world's renewable resources. It is a movement long overdue and vastly underrated in its significance. The attitude of corn refiners and sugar cane processors is important. Progress can be encouraged by redefining both industries beyond their traditional roles as suppliers of nutritive sweeteners, and by concentrating energies on a broad spectrum of opportunities rather than a limited group of products.

The Politics of Sugarcane

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I have been asked to talk about the politics of sugar.

I would not argue much about whether sugar should be a political commodity. The fact that it is a political commodity, it has been for a long time, and it doubtless will continue to be.

It might be a good thing in some respects if all governments would leave the industry alone to grow sugar and market it, and it certainly would be a good thing if governments allowed sugar production and marketing to be based more on normal economic and commercial criteria, with less protection and less other interference with market economics. However, that day is not near at hand. Governments have sugar policies and sugar politics, domestically and internationally, and they will continue to do so.

It is not my purpose to talk about strictly domestic policies, but rather the international side. International sugar politics are brought into a common focus in the International Sugar Agreement and it is about the workings of that agreement and its prospects that I intend to talk.

The Agreement, which was negotiated in 1977, had nearly two years of hard times. Prices were too low. Now it is producing results, and I think both sugar exporting and importing countries can be glad we have an agreement.

The Agreement, for those of you who may not be too familiar with it, is intended to achieve stable conditions in the international trade in sugar, at price levels which are remunerative to producers and equitable to consumers, and to promote equilibrium between supply and demand for sugar within an expanding world sugar trade. There are a number of other important objectives, but all of these either contribute to, or may be expected to flow from, the accomplishment of central objectives I have just cited.

The intended means of accomplishment, in the circumstances of low prices we had when the Agreement came into effect, is, essentially, a system of export quotas and stock building obligations. The stock building obligations are a responsibility of the exporting countries, but are intended to be assisted financially through contributions levied on sugar exported or imported by member countries and loans from the funds so acquired to the exporting members which hold the

stocks.

We have 58 member countries, 42 exporters and 16 importers, including all the major exporters except the European Community and the most important importers, though not most of the less sizeable importing countries.

The exporting countries which joined the Agreement have carried out their responsibilities. They have abided by their export quotas while quotas were in effect and they have met their obligations to accumulate special stocks.

In spite of this good performance, the Agreement could hardly be considered a success for the first year and nine months after it came into effect on Janaury 1, 1978. The intended price range of the Agreement is 11 to 21 US cents per pound for raw sugar. As against this, the ISA daily price in 1978 averaged 7.81 cents, varying from a high of 9.30 to a low of 6.03, and in the first nine months of 1979 it averaged around 8.40 cents, with a high of 10.59, this in September, and a low of 7.42. There was a definite improvement in September, but on October 15, 1979, the 15 day average ISA prevailing price still stood below 11 cents a pound.

Now these prices are not remunerative to any producers that I know of, and, in this sense, the Agreement could not be said to be working successfully.

In some other senses it was working. The first test of course is what would have happened without it. While no one can measure at all precisely what would have been, the experts I know are unanimous, or nearly so, that prices in the low period of 78-79 would have been substantially still lower had there been no agreement. Without export quotas and stocks laid away, there would have been more sugar on the market and this would have had an adverse effect on prices, even already low prices. One experienced observer says perhaps 30-35% lower prices. The exporting countries have benefited by this margin, or whatever the margin has been.

The second test is the conditions that were being established for the future, what would happen now and in the future, with the Sugar Agreement and without it.

What already has happened is a rather rapid increase in prices in the last months of 1979 and the beginning of 1980. Between mid-October and mid-January the price went from below the 11 cent minimum to above the level of 15 cents, where all export quotas were suspended, and, in doing this, it passed through the action band of 13 to 15 cents, where quotas are to be increased, in the two month period from mid-November to mid-January. On January 24 the ISA daily price reached 20 cents.

This represents a success for the Agreement, quite obviously for the exporters,

but I think for the importers too, considering the likely alternative.

Without the Agreement, the low prices of 78 and 79 would have been lower. There would have been no export quotas, but lower prices would soon have begun to mean lower production as the most sub-marginal producers ceased to plant or to grind. It would have meant still lower prices for consumers at the time, but the lower production that would inevitably have followed still lower prices would very probably have been followed, sooner or later, by a shortage and a sharp rise in prices, sharper than that which we have had. And this is what the sugar importing countries should bear in mind. I'm sure they would not want a repeat of 1974, and this is what the lack of an Agreement sooner or later would have brought about.

The prices we have had for the past two years and the Agreement's quota provisions have meant maintenance of at least a reasonable level of production and productive capacity, and the higher prices we have now will mean increased production. I think they will mean enough production to meet all real non-speculative needs at equitable prices.

Up to a point, I think the recent increase in prices can be considered a success for the Agreement. Prices have risen to levels where they ought to be, where market forces can be allowed to govern, where most producers can make some money, and where importers, if they want to avoid really high prices, should not complain. In any case, after the low and unremunerative prices of the past three years, I think importers should not begrudge the exporting countries a decent price of sugar for a while. The question and problem we have now, however, is whether prices will go too high.

I have already mentioned the sharp rise in world sugar prices since September. Now of course this did not result simply from the cumulative effects of the Sugar Agreement. The Agreement did have the effect of keeping off the market the 2 million tons of sugar which members have been obliged to accumulate in special stocks in 1978 and 79. It certainly kept additional quantities off the market until recently because of export quotas, and it doubtless meant reduced plantings and grindings by exporting member countries, though it is impossible to quantify these effect with even a reasonable degree of accuracy.

The additional factors we have seen operating in the last few months include poor crop results, actual or anticipated, in a number of important producing countries —— these include Cuba, India, Thailand and the Soviet Union —— which have led to estimates of a negative production/consumption balance for the current year, and some significant factors outside the purview of the sugar industry, notably the growing mistrust of currencies, which led to a move toward metals and other commodities in the late months of last year. Nor can we dismiss speculation as a factor.

A question that puzzles me is why the New York spot price has been per-

sistently lower than the London price, especially in recent months, even though they are calculated on a basis that makes them comparable. In December the New York daily spot price averaged 79 points (i.e. 79/100 of a cent) lower than the London price, and it also was substantially lower in January. New York is five hours behind London, so you might expect somewhat lower average daily prices in a falling market, but this has been a rising market, in which, all things being equal, the average New York daily price should slightly exceed the London daily price.

Both of these prices of course are more artificial than real, and they are arrived at by consulting quite different people, but this does not make readily apparent why there should be a bias, to be higher or lower, on the part of one as compared to the other. I don't know why this difference has existed, but I'd like to find out.

Incidentally, the use of the lower New York spot price, which was reinstituted in August and which the Sugar Organization began to use along with the London price in October, meant a delay in the suspension of export quotas as compared to what would have happened if we had continued to use only the London price. On the basis of the London price alone, the ISA prevailing price would have passed the trigger point for the release of all quotas on December 21, or some three weeks earlier than it was reached, on January 15.

Now, as to our problems, aside from the initial situation we faced, an excess supply of sugar in the world and too low prices, the main problems of the Sugar Agreement and the International Sugar Organization —— our current political problems — have been difficulties of non-participation. Specifically, we have had three problems: the question whether the largest importer, the United States, could participate definitively in the Agreement; the non-participation of a large number of smaller but still significant importing countries; and, probably most important, the non-participation of the European Community, which has become the largest exporter to the world free market.

The problem of the United States in moving from provisional to definitive participation in the Agreement and the Organization has been the lack of approval by the Senate for ratification of the Agreement and the lack of legislative authority to implement the Agreement's provisions for contributions to the Stock Financing Fund.

The first of these problems has now been remedied; the Senate gave its advice and consent on November 30, by a vote of 80 to 11, and the ratification process was completed on January 2. Needless to say, this action was an important boost to the Agreement; it means continued U. S. participation in the Agreement and removal of the doubt which had been casting a large shadow over our prospects.

We hope that the implementing legislation for the United States to ensure the

payment of contributions for the Stock Financing Fund will follow shortly. Without it, and without the participation of the US, other members have considered that their own implementation would be discriminatory and the whole project —— the Stock Financing Fund —— has had to be deferred. However, the Ways and Means Committee has reported this legislation to the House of Representatives and we hope action on it will be completed in the very near future.

Our second problem, the non-participation of other importers, is a difficult problem to deal with. Of course participation or non-participation is a question for each prospective member to decide in the light of its own interests. We hope, however, that, in considering participation, importing countries which are not now members will take a broad and long-term view of their interests. It makes me a little sad, in fact, to consider that nearly all of these countries are developing countries, and they are not showing, in this instance, the solidarity with their developing country sugar producing friends to which they have so strongly subscribed in many world forums.

Part of this problem is that a high percentage of the imports of many of these non-members comes from exporting non-members, and this contributes to relatively unrestrained exports by those non-members, and this contributes in turn to the difficulty of resolving our third problem.

That problem, which probably has been our most serious problem, is the non-participation by the EEC. The Community is not a member of our Organization and it does not assume any equivalent obligations. Hence, while our exporting members limited and reduced their exports in an effort to right the balance of supply and demand, the Community has undertaken no equivalent restraint and continued and increased a high level of exports based on heavy subsidization. Sugar export subsidies cost the Community something around $840 million in 1978 and close to a billion dollars in 1979, and the amount of the subsidy per pound frequently was well above the world price. With this regime, the EEC has moved from a net importer of sugar as recently as 1976 to a very major net exporter, and the largest exporter to the world free market.

Understandably, our exporting members feel they have a grievance.

While we continue to hope for Community participation in the Agreement, or for close co-operation, the prospect looks pretty dim. The Commission has proposed cutbacks in quotas in the hope of reducing the burden of export subsidies. For the next five years it has proposed to reduce the A quota from 9,136,000 tons to 8,686,000 tons and the B quota from 27½% to 20% of the A quota. This would mean a total reduction of 1,254,000 tons of subsidized sugar.

However, these proposals have already met strong opposition, based mainly on the politically strong farm area interests which are largely responsible for the

Community's sugar policy. These political interests are strong, and their opposition has been encouraged by the prospect of reduction of world sugar stocks and the rise in world market prices, which encourage the public in the Community countries to think a very high level of European production is needed and have the effect of decreasing the cost of overproduction in the Community by reducing the cost of export subsidies.

The lack of effective restraints on production when prices are low is not consistent with our members' view of obligations under the Agreement.

The present Sugar Agreement has three years to run, even without extension, and it is too early to think very hard about what changes should be made in the next one, aside from some arrangement for Community participation. One thing most of us have concluded from the recent experience, however, is that the band of prices which activate increases or decreases in the global export quota is too narrow.

For prices moving upward, the global quota is increased by 5 per cent at 13 cents, 5 per cent at 14 cents, and 5 per cent at 14½ cents, and all quotas are suspended at 15 cents. The prevailing price moved through all of these trigger points in a period of just two months, from November 12 last year, when it was below 13 cents, to January 14, when it was over 15 cents for the necessary five days. This does not afford much opportunity to test the market with additional supplies before all quota restraints are gone.

Of course many of our exporting members would say we wouldn't have moved through the action band so fast if we had adjusted the prices in the Agreement upward when we should have done so, by which they mean last November. However, there were what seemed good and adequate reasons at the time why some members opposed an upward adjustment in prices at our meetings in November. In any case, it was agreed to review the prices in the Agreement early in the new year, and it has been agreed to start this review towards the end of this month and complete it in March.

Under the pertinent provisions of the Agreement, any adjustment of prices must maintain the difference between the minimum and maximum prices of the Agreement, i.e. a difference of 10 cents a pound. Since the effects of inflation or deflation and of changes in exchange rates is a major part of the basis of the price review, I think it is generally accepted, though not mandatory in the words of the Agreement, that an adjustment of the upper and lower prices would be accompanied by a similar adjustment of the trigger point prices. For instance, if the minimum and maximum prices are raised from the present 11 and 21 cents to 12 and 22 cents, the trigger point for mandatory release of export quotas probably would be raised from 15 to 16 and the trigger for mandatory reinstatement of quotas would be 15 instead of 14. An agreement to this effect in March, therefore, would mean mandatory reinstatement of quotas if the prevailing price is then below 15 cents.

I should note in this context, however, that a change in this direction in March would not mean very much for 1980 if there have been no quotas in effect until then since export deliveries and sales for early delivery during the period when there are no quotas need not be counted in the reinstated quotas.

In these circumstances, aside from the 2 million tons of special stocks our exporting members retain, the supply of sugar on the world market and the price of sugar for the remainder of 1980 is likely to be fully subject to commercial market factors, to the extent they are ever allowed to operate for sugar, and not dependent on further actions of the International Sugar Organization. The actions under the Sugar Agreement which will continue to be felt in 1980 have already taken place in 1978 and 1979, notably the limits on exports and the withdrawal of sugar from the market to accumulate special stocks which were enforced in those years.

In addition to the price review, we are also embarking on another major exercise in March, and that is the renegotiation of the basic export tonnages in the Agreement. I suspect this renegotiation will be taken a little less seriously by our members now that quotas are suspended than it might have been in other circumstances, but it is still taken seriously enough since the results could be very important to exporting countries if prices should fall and limitations on exports should be re-established.

The basis of the renegotiation is provided in the Agreement, but suffice it to say that it has a lot to do with export performance in the first two years of the Agreement. In fact there is a fall back formula in the Agreement in case the negotiation does not produce agreed results and this depends essentially on the old basic export tonnages plus export performance.

Neither the renegotiation nor the fall back formula, if it is used, is likely to produce any very drastic changes for 1980, though greater changes are possible in the ensuing years as we move farther from the time the Agreement was negotiated. There will also be important changes for some of our smaller producer members who will benefit from the special provision made for the expansion projects they registered when the Agreement came into force.

What else of the future?

For the immediate future, the experts are predicting a balance in the current crop year —– from September/October 1979 to the same date in 1980—– of some 3 to 4 million tons excess of consumption over production. These estimates of course are a major reason for the strong increase in prices. They do not lead us to a really clear picture, however, because there is no clear picture of the level of existing stocks in relation to normal commercial holdings. The market must think stocks are not very high, at least not as high as they have been assumed to be. However, one of the foremost experts, an expert with a good reputation for objectivity, says

there will be a free market export availability of more than one million tons over requirements this year.

This estimate excludes the special stocks which our exporters hold under the provisions of the Sugar Agreement. Some rumors to the contrary notwithstanding, these stocks do exist, and, with some minor discrepancies, in the amounts intended. As of December 31, they amounted to 2,004,775 tons against the 2 million tons intended under the Agreement. They of course have been verified by our inspectors on a pre-determined schedule.

These special stocks will not come on the market unless the 15 day average prevailing price passes the trigger points set in the Agreement, beginning at 19 cents. If it does pass that point, and it now looks very much as if it will, the presumption is that one third of the exporting members' total stockholding obligation, or 833,000 tons, will be released on to the market. Another 833,000 tons is to be released at 20 cents. I think these supplies are very likely to cool the market.

Even without these special stocks, it seems reasonable to suppose there is enough sugar to meet all requirements and there will be no shortage. On the other hand, prices should remain strong throughout the year.

It also seems reasonable to expect relatively favorable prices for the next few years, provided there is not an explosion of increased production but a moderate expansion in line with the anticipated gradual increase in demand.

In the longer run, the FAO has recently produced projections showing a 2.6 per cent a year increase in production for 1976-1985, with developing countries accounting for 70 per cent of the increase, stimulated primarily by expanding domestic markets. Their consumption estimates also show an annual increase of 2.6 per cent for the same period. Developing countries will produce, import, and eat more sugar, they say, and developed countries will import less.

One factor in the developed country markets is the increasing use of high fructose corn syrup (or isoglucose) in place of sugar, particularly in the United States. There is no doubt the growth of this product will continue; the question is how much, and this is a function of the price of sugar and the price of corn, among other things, not excluding political factors.

Alternative use of sugar cane to produce alcohol for motor fuel also is a potentially important consideration, particularly as oil prices increase. This could be especially significant as a long-run factor, though, in view of location and other factors, it should not be assumed that cane supplies can readily be shifted back and forth between alcohol and sugar production.

In the short run and the long run we of course want to control the sugar cycle, for the benefit of producers and consumers. The next few years should tell us a lot, perhaps especially the next few months.

The Use of Sugar

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It is a pleasure to be in a country that is one of the world's largest producers of cane sugar, and a very real honor to be asked to address this distinguished gathering. I have been asked to say that the views expressed herein are those of your author, not those of The Coca-Cola Company.

The topic herewith is "The Use of Sugar." The use of sugar is something that, doubtless, the members of this group have affected and been affected by for most of their careers. So, obviously it is a topic in which you are acutely interested. In much the same way, the topic is one in which your author is deeply interested.

Sugar has been a personal love for over a quarter of a century. Your author assisted in the formation of the United States post-war sugar policy, and with the firm's staff made many improvements in Coca-Cola operations over the years. The use of sugar as the primary ingredient has been crucial to the production of Coca-Cola and most of the firm's other products since their development.

Coca-Cola USA is responsible for supplying sugar for 41 different locations, *i.e.*, syrup plants and Foods Division plants. This sugar is an ingredient in over 65 products produced at these plants. These factories have a combined use of several thousand tonnes a day, making this company the world's largest user of sugar. Almost all of this sugar is shipped in the form of dry bulk sugar in jumbo "airslide" cars, or in bulk trucks.

Coca-Cola's sugar purchasing is totally centralized. The Purchasing Department has responsibility for the logistics as well as the buying of sugar. While the firm's use is restricted to refined sugar of very high quality, it is a large buyer of raw sugar that which has been refined under "tolling" agreements.

Speaking of quality, the company has often regarded as one of the most demanding customers of the industry in the United States. This is because Coca-Colas has steadfastly refused to accept sugar that does not meet company specifications. Coca-Cola's stand in this respect has helped to upgrade the quality of sugar throughout the United States. In fact, the ability of the United States cane sugar refining industry to produce and ship properly cured granulated sugar in bulk is, in large measure, the result of a joint development effort between Coca-Cola and the industry. Furthermore, Coca-Cola is quite willing to be of assistance elsewhere in the world if there is a request from the industry.

Coca-Cola's North America's purchase of sugar is limited to requirements within the United States. Throughout the rest of the world, most of the sugar needed is purchased by the local franchised bottler. As many are doubtless aware, the refined sugar available most places in the world does not meet Coke's high-quality standards. It is necessary for the local bottler to upgrade the quality by filtration or, in some cases, even by ion exchange.

Sugar usage is probably one of the most dynamic, changing facets of this age-old industry. The growth in the variety of non-food uses is well known to all. In Brazil, diversified use of sugar has grown through the expansion of the national alcohol production program. It has grown to the extent that Brazil's goal for the 1979-1980 harvest year would require no less than 41 percent of the nation's cane to be devoted to production of fuel alcohol. Now, while this program of alcohol production has been in operation in Brazil for 50 years, the growth in volume and technology that has occurred there in the past one or two years has been nothing less than overwhelming. This phenomenon must continue to occur elsewhere, as nations are forced to evaluate alternate sources of energy, due to the skyrocketing price of oil. In this regard, the production of fuel alcohol is receiving a high priority by the government of The Philippines.

Numerous other countries are examining the economics of alcohol from sugar cane and are developing fermentation programs to supplement their national fuel requirements and lessen the import of foreign oil. Hawaii, the leading sugar-producing state in the United States, has begun a pilot project to produce alcohol from cane. The industry there is also in the process of examining the possibility of more similar programs, including the production of alcohol from molasses. Their programs include an examination of all aspects of energy from cane, including growing techniques to maximize the amount of energy per hectare.

Also in the United States, the Commodity Credit Corporation has been guaranteeing loans up to US $15 million to finance pilot energy projects. The very first of these loans was made to a joint venture which is constructing a facility to produce alcohol from cane residue.

Tate & Lyle has embarked on a $39 million project to develop new uses for sugar. The firm presently has developed over 150 sucrose-based chemicals.

Interesting and important as these developments are as possible ways of alleviating the energy crisis, the first and foremost interest in the use of sugar is still, and will continue to be, its food uses. Coca-Cola's reliance on the sugar industry through the years to provide its major ingredient and your author's involvement in procurement of sugar have resulted in a long, and hopefully, mutually beneficial relationship with the sugar industry.

Sugar has always been regarded throughout the countries of the world as one of the good things of life. Among food items, it is one of the most basic luxuries, as well as a very low-cost source of food energy. It is the food

whose consumption grows most dramatically with economic improvements in a country. When people have more discretionary income, their consumption of the good things increases.

This has certainly been seen in the increase in consumption that has occurred in the developing countries of the world as their standards of living have improved. India's domestic consumption of sugar, as food, for 1978 was up 30 percent over 1976; China's was up 27 percent for the same period; Sri Lanka's consumption was up 165 percent. These are not isolated examples. These are clear indications of what occurs and what will continue to occur in areas of the world that are just beginning to show an economic improvement. Sugar will continue to serve people, not only as an inexpensive food source, but also as a basic luxury. The implications of this for growth in the use of sugar cannot be ignored.

Throughout the world, we at Coca-Cola have seen consumption of the firm's products rise dramatically as economic stability and well-being have advanced. Indeed, this phenomenal growth has occurred to the extent that the domestic, *i.e.,* United States, segment is no longer the largest part of Coca-Cola sales.

Another area of growing and diversified use that industrial users are witnessing is related to the importance of convenience and value to today's consumers. More and more "sugar-added" products are experiencing popularity with buyers who want the lower cost of a product they can mix themselves, *e.g.,* powdered soft drinks, with the convenience of sugar already included. Increased usage in this type of item will, no doubt, increase the need for sugar as the citizens of developed countries demand more ease of preparation.

This leads to a discussion of two movements, or factors, that have recently been viewed by the cane and beet sugar industry as threats. The corn wet-milling industry has developed a product, high-fructose corn syrup, that is another nutritive sweetener, another sugar (or isoglucose, as it is called in some countries). Indeed, in acidified products cane and beet sugar invert actually assume for all practical purposes the identical properties of High-Fructose Corn Syrup. Considering the ramifications of a product such as this, there is no doubt about one thing. In countries that are not self sufficient in cane and beet sugar production, where High-Fructose Syrups can be made available at a competitive price, it will play a larger role than in other areas. But, a role is *all* it will play. It is merely one more type of sugar in the array of sweeteners which are available to consumers. For some applications, it will possibly grow in popularity and use, but it could hardly become suitable for *all* applications. There is little doubt that the world, in coming years, will need all of the nutritive sweeteners that can be produced.

The second situation that must be addressed is that the attacks made on sugar by health faddists. This is more common in the developed countries. Charges are levelled at sugar and sugar products as "empty calories," "bad for dental health," and so on. In some ways, this has been tied in with the

fructose issue. Fructose has been hailed as the "natural sweetener" – "the sweetener found in fruit." Fructose is no more natural than other nutritive sweeteners, or superior to them. The fact is that, although it lacks vitamins and minerals, refined sugar is an ideal source of energy. How can a calorie be "empty" – this is a misstatement of fact. It provides the fuel the body needs to be active. This is a crucial need in the developing countries, where food is not plentifully available. Even in developed areas, it is a convenient and fast source of energy. The value of this should never be ignored.

Your author is happy that the industry is beginning to "fight back" on this issue of the value of sugar as a food. Studies have been done to show that the potentialsdental threat of sugar is not greater than that of other sweeteners derived from fruit or corn. The value of sugar as an energy source is being more widely publicized by the industry and that is good.

Finally, a few words should be said about the International Sugar Agreement (I.S.A.) and its move toward full implementation. It has been received well by a large majority of importers and exporters. Parenthetically, your author had the pleasure to be an advisor to the United States Delegation in Geneva both in 1973 and 1977 and is aware how difficult it was to reach the present I.S.A. agreement.

Despite the obstacle the United States has had to overcome in its move toward ratification and implementation, it has adhered to the rules of the I.S.A., as have the other participants. The Agreement has worked well to date. The world price has risen to a profitable level for producing countries. However, the results of the current wave of speculation in gold, silver and, now in sugar, does not augur well for the future expanded use of sugar. The current price of world raw sugar is not justified by the fundamentals of supply and demand. A word of caution is in order, and, as the Agreement continues to exert its controls, one can look forward to a sugar market where user and producer alike receive "good value for a fair price paid."

The Sugar Industry in a Changing Economic Climate

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Since 1951, world consumption of centrifugal sugar has increased on average by just over two million tonnes, raw value, per year. The relative rate of growth has successively dropped from 4.9 percent a year, in the period 1952-1960, to 3.9 percent, in 1961-1970 and then 2.5 percent, in the 1971-1978. If sugar continues to be used almost exclusively as a food, past performance points to a demand for centrifugal sugar of the order of 103 million tonnes, raw value, in 1985 — 11 million tonnes above the 1978 production level — and of 113 million tonnes in 1990. The implication is that the average annual rate of growth will be 2.1 percent in this decade.

Moreover, due to the development of high-fructose corn syrups (HFCS or isoglucose), the market for sugar in developed countries is now vulnerable to attack by substitutes as it has never before been. In 1979, less than a decade after their commercial introduction, world sales of HFCS reached an estimated two million tonnes, dry basis. In the United States, the leading producer, HFCS has mainly affected sucrose consumption, although it also appears to have slowed down the growth rate of conventional starch sweetener usage. Relative to total U.S. per-capita caloric sweetener consumption, per-capita sugar consumption declined from 86.8 percent in 1962 to 83.0 percent in 1970 and 69.9 percent in 1979. While the economics of isoglucose manufacture and its market potential vary considerably in different countries, it generally offers a cost advantage to industrial users. Competition from cheaper substitutes is bound to restrain the upward movement of the sugar price and limit the ability of the sugar industry to pass increases in production costs on to the consumer.

Probably no other factor will determine the development of the sugar industry in the 1980's as much as the changed energy situation. The price of a barrel of Saudi Arabian light crude oil, traditionally the reference point for oil prices, rose from US$1.90 in 1972 to $24 at the end of 1979. At the 1972 oil price and that year's average International Sugar Agreement Daily Price of $0.0727 per pound, a barrel of oil cost about 26 pounds of sugar. At their respective prices toward the end of 1979, a barrel of oil was worth about 160 pounds of sugar.

A change of such magnitude calls for a reassessment of production methods in field, factory and refinery, as well as for a review of research and development objectives. Energy management is likely to become the principal concern of sugar technologists in the 1980's, replacing the reduction of manpower requirements and the increase of sugar yields as the main goal

of technical innovation.

In the field, both the consumption of such items as fertilizers, fuel and electricity, and the methods of production will be scrutinized to effect savings in on-farm energy use. In the factories, and above all in cane sugar mills, the main objective henceforth will almost certainly be to improve thermal efficiency. Whereas efficient bagasse combustion and economic steam utilization would make enough energy available in an integrated plant to produce white sugar without additional fuel, the refining of raw cane sugar entails relatively large support energy costs. The escalation of fuel prices can be expected to revive the debate over the respective economic advantages of manufacturing plantation white sugar directly from cane versus refining from raw sugar.

Other things being equal, the competitive position of those sugar producers relatively less dependent on purchased fuel obviously improves in the new energy situation. Available studies indicate that, as a rule, sugar cane has a marked advantage over sugar beet, both in terms of gross biomass energy yield and the ratio of energy output to support energy input. Whereas cane bagasse provides most of the energy for the production of raw and plantation white sugars, sugar beet supplies no energy for processing. Modern beet sugar factories consume about a tonne of fuel oil for each three tonnes of white sugar, including the energy required for pulp drying.

In a world of runaway fossil fuel prices, energy output:input ratios take their place alongside the more familiar yardsticks of labor and capital costs as standards of economic comparison in the sugar industry. Both beet and cane sugar producers face the prospect of an acceleration in the rising trend of production costs. To cope with the continuous cost squeeze to be expected in the changed economic environment, the sugar industry will have to seek the efficient exploitation of all parts of the beet and cane crops.

The kind of systems approach required to save energy and to optimize the utilization of the produced biomass will also help the sugar industry to take advantage of the new opportunities presented by the oil crisis. Sugar cane, in particular, has excited attention as a renewable source of energy. Brazil has been the first country to initiate a large-scale program to produce fermentation alcohol for motor fuel, not only from the molasses, but, to an increasing extent, directly from cane juice, which implies a great expansion of the area under cane.

The declining growth rate of the food demand for sugar, increased competition from starch sweeteners and the rise of fossil fuel prices will exact their toll of adjustments in the sugar industry. Rooted in biomass systems capable of yielding a variable product mix of food, materials and energy, the industry has the ability to adapt to the new situation. The challenge of the 1980's is to use that ability.

Some econmic Implications of Power Alcohol

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INTRODUCTION

Liquid fuel has become firmly established as the most acceptable and, in many cases, the most economically viable source of energy for road vehicles. With its convenient properties and almost universal availability, alcohol has been considered as a possible motor fuel throughout virtually the entire history of the internal combustion engine.

Ethanol-petrol mixtures in various proportions have been used from time to time in many countries, for example, Brazil, Eire, France, Germany, S. Africa and the U.K. but, because of the then low petrol prices, they were not considered seriously. In the face of rapidly rising hydrocarbon fossil fuel prices, many countries are considering substituting a part of their petrol with alcohol manufactured from suitable agricultural crops. The advantages of a motor fuel derived from such regenerable sources are listed as follows:

a) considerable savings of hard currency on oil imports
b) some control over the availability of a part of the motor fuel requirement
c) stimulation of domestic agricultural industry

In addition, there is growing interest in the use of alcohol as a substitute for naptha in the manufacture of petro-chemical derivatives. Ethanol can readily be converted into ethylene, the primary building block for a wide range of common products like polyethylene and polyvinyl chloride.

The concept of power alcohol is therefore of greatest interest to those countries which do not have their own adequate oil reserves but which do have an abundance of sunshine and water to grow the necessary feedstock crops.

The revival of interest can be traced directly to events in Brazil following the announcement of the "PROALCOOL" energy programme of November 1975. Many other countries are now studying the possibility of following the lead set by Brazil, and some have already embarked on the first stages of a national power alcohol programme, e.g. USA, Philippines and Sudan. Each country has adopted a somewhat different attitude towards its own programme and this paper attempts to describe the relationship between various technical and economic aspects.

THE TECHNOLOGY OF POWER ALCOHOL MANUFACTURE

Raw Material Feedstocks

Alcohol is manufactured by fermentation of a carbohydrate (sugar or starch) crop followed by distillation to separate and purify the alcohol (it must be anhydrous if it is to be blended with petrol). Many factors influence the choice of raw material, but the most important relate to the resources which are available in any country.

If a crop is to be grown specifically for conversion to alcohol then its yield is important: the table below shows the approximate yield of alcohol per hectare per annum for six crops: –

Crop	Crop Yield t/ha/year	Alcohol Yield 1/t	Alcohol Yield 1/ha/year
Sugar Cane	40 – 120	70	2800 – 8400
Cassava	10 – 40	180	1800 – 7200
Sweet Potato	10 – 40	125	1250 – 5000
Sugar Beet	10 – 40	120	1200 – 4800
Sweet Sorghum	20 – 60	55	1100 – 3300
Maize (corn)	1 – 4	400	400 – 1600

The growing of a specific crop for power alcohol demands not only that the necessary resources (land, people and finance) are available but also that they can be organized efficiently.

In addition to the agricultural costs, the processing costs can also be important. With starchy crops like cassava or corn, the starch must first be extracted and converted to sugars (saccharification) ready for the fermentation. In the case of cassava, the roots must be processed within a day or so of gathering in order to prevent decay, although partial processing e.g. to dried chips, is a possible alternative and is essential if year-round operation is desired.

Processing costs are minimized if liquid sugar materials are already available, either in the form of molasses, or as a sugar syrup from a sugar factory.

In the context of a world energy crisis, the energy balance is also important and power alcohol production should show a net energy gain. One of the most important factors in this balance is the amount of energy required to operate the alcohol production unit, and it is here that sugar cane shows a significant advantage. Sugar cane provides both the fermentable sugars and the bagasse fuel simultaneously. In fact, sugar cane provides more bagasse fuel than is actually required to process the cane juice, so that bagasse can be accumulated during crop to power the plant

during the out-of-crop season on some alternative feedstock, e.g. stored thick syrup; molasses from neighboring factories, cassava or cassava starch. Syrup and molasses offer the advantage that they can be fermented directly but a saccharification facility greatly increases the flexibility of the plant to accept almost any fermentable feedstock. In this way, the installed plant capacity can be utilized throughout the whole year, instead of being limited to the availability of a particular crop.

Some crops have a negative overall energy gain but this does not rule them out of court; they may be in temporary surplus, or surplus to a stabilized market (e.g. corn in the USA), or they may offer the opportunity to turn an inconvenient solid fuel (wood or coal) into a convenient liquid fuel and this could be worth some energy loss.

The following examples may illustrate the range of possibilities:

Brazil

In setting its target volume of alcohol production, Brazil has predetermined the total quantity of fermentable feedstock required and the most readily available material initially was molasses, one of the by-products of the sugar industry. However, Brazil does not have enough molasses to make its target volume of alcohol, so it has turned to sugar cane juice, processed either in specially built so-called autonomous distilleries or in distilleries appended to sugar factories, and to the starchy root crop cassava. Mention should also be made of the potential for using Babacu nuts which is under active investigation and trial.

Thailand

Thailand has a strong agricultural economy and a wide variety of fermentable crops (cane sugar, tapioca, maize and rice). Under the conditions of a bumper crop and low world prices, surpluses would be channelled into power alcohol, thereby stabilizing the domestic agricultural market and facilitating long term plans. Technical problems will be serious and investment costs high, but the prize would be partial substitution of oil imports.

Sudan

With a fast growing sugar industry and a transportation infrastructure incapable of handling its by-product molasses, Sudan is facing the prospect of having to dump its molasses in the desert. Instead, it is now considering a power alcohol programme based on the utilization of what would otherwise be a waste product.

Many other developing countries have stated their interest in power alcohol based on agricultural product. Colombia, Cuba and the Philippines are examining the use of cane juice, Papua New Guinea, cassava, and Ivory Coast, molasses.

In the developed countries, the USA is likely to proceed with a corn-based alcohol programme, possibly looking to sugar cane in Louisiana and Puerto Rico, while in Europe the choice of a suitable fermentable crop is not so obvious.

Processing

Sugar cane must be shredded and milled to separate juice from bagasse. This is the conventional first stage of sugar manufacture and the technology is very well established. Molasses requires only dilution and clarification, and is therefore the simplest feedstock available.

Starch crops like cassava or corn must be milled, pulverized or shredded prior to the saccharification stage, and while this process is well established with corn (being the first stage of corn syrup manufacture), Brazil has had to develop processes suitable for cassava.

The conversion of sugars to alcohol is carried out by yeast fermentation under carefully controlled, but well understood conditions. The same process is used conventionally to produce potable spirit. Most fermentation processes installed today are batch systems, but it is worth adding that increasing attention is being given to the possible adaptation of continuous processes, with the objective of reducing capital cost.

After fermentation the alcohol is separated by distillation, and three stages are recognized: stripping, rectification and dehydration. The latter requires the addition (and, of course, recovery) of a third component, usually benzene or cyclohezane, to remove the last traces of water from the alcohol.

Effluents

The residue from distillation, called "vinasse" or "slops", present a major pollution problem and several countries e.g. Australia and Thailand, have stated that they will not proceed with a power alcohol programme until they have been assured that adequate effluent treatment systems are available. The "slops" contain valuable minerals, notably potash with some phosphate, which should be returned to the field. The best solution, in many cases, involves primary treatment only, with the effluent water pumped back to an irrigation system. However, such a method can only be used where the distillery is located in an estate, the lands of which fall under the same authority as the distillery itself. Where irrigation is not possible, activated sludge treatment is generally found to be too expensive and evaporation methods are chosen either to produce an animal feed product or for incineration. Anaerobic digestion processes, which would yield methane fuel, are under active development in several countries.

THE DEVELOPMENT OF NATIONAL POWER ALCOHOL PROGRAMMES

Although many countries are now considering power alcohol as a substitute for oil, it is extremely hazardous to generalize about the economics of production. Each country has a variety of resources available at different costs and different market prices and evaluation of these is fundamental to the analysis of a national programme.

The prime resources to be evaluated include land, labor and capital and particular attention must be given to the identification of surplus agricultural produce, and to under-utilized manufacturing capacity. Specific factors include:

Estate and infrastructure development costs.
Agricultural, harvesting and transportation costs.
Purchase price of bought-in fermentables.
Storage Costs.
Factory/Distillery capital and operating costs.
Alcohol storage, distribution and blending costs.
Petrol price, duties and taxes.

In virtually no country has power alcohol stood cleanly on its economic feet when judged at market prices: alcohol appears to be an expensive fuel with a total cost typically approaching US$2/gallon. However, current market prices are not necessarily relevant to the particular analysis: the use of surplus crops or by-products which would otherwise be wasted has already been referred to, and represents a means by which the feedstock costs can be reduced. Alternatively, the conversion of existing distilleries or existing sugar factories can save a large amount of capital expenditure, and low interest Government finance can also help to reduce the capital cost element.

Nevertheless, in most countries of the world, power alcohol today would cost more than petrol, and without Government stimulation and support it is doubtful whether a power alcohol industry could be considered viable. In the USA Gasohol Programme, for example, the combination of State tax and Federal excise tax rebates can amount to as much as US$1.20 per gallon of alcohol, compared with the current pump price of petrol around US$1.10 per gallon.

Apart from the domestic economic analysis, the national economic objectives must be identified. Power alcohol programmes can residue imports of oil and benefit the balance of payments as well as providing opportunities for economic development in both the agricultural and industrial sectors. Power alcohol can also contribute to strategic objectives, by reducing dependency on imported oil and by developing or stabilizing specific sectors of the economy.

For these reasons, it is perhaps, not surprising that different countries have

adopted different attitudes to power alcohol. With the proviso that the distinctions will probably tend to blur as the programme is implemented, the following three basic concepts have emerged.

The Target Volume

Brazil has set a series of targets for the volume of alcohol to be produced by successive dates. The capacity of authorized distilleries already exceeds 4½ billion liters p.a. and the alcohol content of petrol reached 12% in 1978. The target is now to produce up to 10.7 billion liters p.a. by 1985, by which time alcohol will provide nearly 5% of Brazil's total energy requirements.

This concept is likely to predominate in smaller countries where the target volume of alcohol production can be related with a specific agricultural development programme. In Zamba, for example, 5000 hectares of additional sugar cane would yield sufficient alcohol for a national 15% blend.

The Economic Regulator

This is the concept in Thailand where surplus crops would be converted to power alcohol to stabilize domestic prices for agricultural product and oil imports would be reduced accordingly. With its focus on corn, the USA might appear to be following this concept, which is clearly attractive to all countries with a dominant agricultural economy.

Waste Product Utilization

Sudan has already been mentioned as the example where surplus molasses is available too far from export markets to have a positive value. A power alcohol programme could convert this into a valuable substitute for oil imports. The possible utilization of waste agricultural products in this way is obviously attractive in many other countries.

INTERNATIONAL IMPLICATIONS

The choice of molasses and sugar cane as raw materials has had important implications for the world trading markets for molasses and raw sugar and for the economics of sugar production. Two particular aspects are referred to here.

Market Flexibility

The diversion of molasses to alcohol production in Brazil has strongly influenced the world price of molasses which is currently at an all-time high level. At the same time, there is a price at which it is more profitable, even for Brazil, to sell molasses on the export market and buy oil. This is a new situation which

will surely be exploited by all countries with a molasses export potential, especially those with the capacity to grow additional sugar cane.

The question of sugar exports is even more interesting. Under the terms of the International Sugar Agreement, exports of sugar are currently restricted to agreed quotas. However, should the world price of raw sugar rise above certain levels, these quotas are progressively increased and finally abandoned: historically, it has not been possible to raise production quickly enough to prevent dramatic surges in the world sugar price which in turn are followed by over production and low prices again.

Brazil, the world's largest producer of cane sugar, now has the advantage of being able to increase rapidly its sugar exports when these are profitable: a 20% increase in sugar exports would require only 10% of the sugar cane needed for the PROALCOOL plan, and much of the necessary production capacity is already available. Should Brazil choose to exercise this option to switch cane production from alcohol to sugar exports, then the whole nature of the world sugar economy will be changed: the effects will depend on the magnitude of the switch but could include the stabilization of world sugar prices at higher levels than those to which we are accustomed. The implications for all sugar exporting countries are very significant.

Operating Flexibility

The addition of a power alcohol distillery to a sugar factory gives the producer some choice over the mix' of his products. Normally, the molasses/sugar ratio is largely dependent on the cane quality and factory efficiency, the objective being the extraction of the maximum amount of sugar from the cane. But with a distillery attached, the ratio of molasses/sugar output can be varied to take account of market opportunities, and it is noteworthy that in Brazil, the sugar content of molasses going to the annexed distillery has increased significantly in recent years.

Since complete extraction of all available sugar from molasses is expensive, this increased operating flexibility can also lead to a reduction in cost and improvement in quality of the sugar produced. If the sugar quality reaches the level of the so-called very high polarization raws ($> 99.5^{o}$ Pol), then the costs of subsequent refining can be substantially reduced and the raw sugar can attract a premium price.

CONCLUSIONS

The implications and consequences of national power alcohol programmes are of very considerable international importance. Brazil led the way in developing the first practical alternative to petrol, and other countries are now introducing to the world the means by which certain agricultural commodity markets can be stabilized, to the benefit of a great many people in both producing and consuming countries.

REPORT OF THE STANDING COMMITTEE ON GERMPLASM AND BREEDING

By Don J. Heinz, Chairman

Major activities of the Standing Committee on Germplasm and Breeding since the Sixteenth Congress of the ISSCT in Brazil in 1977 have been the quarantine and distribution of the 1976 Indonesia and 1977 Papua, New Guinea germplasm collection by the U.S. Department of Agriculture (USDA) at Beltsville, Maryland, publication of the ISSCT Sugarcane Breeders Newsletter, and coordination of the two World Collections of Sugarcane Germplasm maintained by the USDA and the Coimbatore Sugarcane Breeding Institute.

GERMPLASM COLLECTION

Sugarcane clones collected in Indonesia in 1976 were quarantined in Brisbane, Australia for one year prior to shipment to the USDA Beltsville, Maryland quarantine station. The Beltsville station was the primary quarantine for all those clones collected in Papua, New Guinea. The New Guinea (NG) clones arrived in Beltsville between late April and early June of 1977 and the Indonesian clones arrived between August and November 1977. Some replacements were sent later for those clones which did not survive the initial shipments. In all, cuttings of 241 NG clones and 472 Indonesian clones were received, of which 141 and 398 clones, respectively, were established at Beltsville.

As of June 1979, 110 NG clones and 150 Indonesian clones had been sent to Ft. Pierce, Florida for a one-year quarantine prior to placement in the World Collection at Miami, Florida. A total of 89 NG clones have been forwarded to India for eventual inclusion in the collection at Cannanore. In addition, 17 NG and 56 Indonesian clones were sent to Barbados and 111 were shippped to Hawaii during 1979.

FINANCES FOR INDONESIAN AND PAPUA, NEW GUINEA EXPEDITIONS AS OF NOVEMBER 1979

Total funds available	US $42,112.00
Expended on the Indonesian Expedition:	($25,970.00)*
Expended on the Papua, New Guinea Expedition:	($10,556.00)
Expended for processing and shipment to world collection:	($ 755.00)
Total Funds Expended	($37,281.00)
Funds returned to ISSCT General Fund:	$ 4,831.00

*Estimated figure reported at 1977 ISSCT Congress—$26,582.00

WORLD GERMPLASM COLLECTIONS

Collection at Miami, Florida

Dr. J. D. Miller, Location Leader, Sugarcane Field Station, Canal Point Florida, reports the USDA has transferred the World Collection of sugarcane and related grasses from Beltsville. Maryland and Canal Point, Florida to 10 acres on the USDA Subtropical Horticulture Research Unit at Miami, Florida. Presently (as of July 1979), the collection consisted of the following clones:

551 *Saccharum officinarum*
261 *Saccharum spontaneum*
64 *Saccharum robustum*
90 *Saccharum sinense*
18 *Saccharum edule*
130 clones of related grasses
156 foreign and historical manmade hybrids
19 clones, unclassified.

The collection is being supervised from and is under the direct control of the Canal Point Station to insure that it receives proper attention.

The number of shipments made from the World Collection and the Canal Point breeding collection were:

Year	*Number of Shipments*	*Number of Clones*
1976	36	304
1977	19	227
1978	27	419

Rust was discovered in the collection at Miami on May 4, 1979, smut is also present in Florida, but has not been found in the collection. As a precautionary measure all cuttings shipped from Canal Point or Miami are given a hot-water treatment of 52°C for 45 minutes and treated with a fungicide. This should provide protection from both rust and smut disease.

All requests for clones from the Miami World Collection should be addressed to:

Sugarcane Field Station
Star Route Box 8
Canal Point, Florida 33438

Collection at Cannanore, India

Dr. K. Mohan Naidu, Director, Sugarcane Breeding Institute, Coimbatore, reports the following clones in the World Collection at Cannanore (as of January 1, 1979):

Number of Clones	*Species*
628	*Saccharum officinarum*
26	*S. barberi*
22	*S. sinense*
37	*S. robustum*
450	*S. spontaneum* (Part maintained at Coimbatore)
23	Ripidium and allied genera
1008	Indian hybrids (Co, CoS, etc.)
591	Foreign hybrids
143	Indo-American (IA) hybrids

Cuttings of 191 clones were sent to eight foreign countries during the year — USA, Egypt, Barbados, Burma, Spain, FAO Rome, Madagascar, and Kenya, and to six stations within India.

All requests for clones from the Cannanore World Collection should be addressed to:

Dr. K. Mohan Naidu, Director
Sugarcane Breeding Institute
Coimbatore–641007
(Tamil Nadu)

ISSCT SUGARCANE BREEDERS' NEWSLETTER

Mr. J.A. Lalouette, former Head of the Biometry and Plant Breeding Division of the Sugar Industry Research Institute, Reduit, Mauritius, has been Editor of the Newsletter for the past three years ending in the Spring of 1980. Mr. Lalouette deserves the recognition and appreciation of his colleagues and the Society of his dedicated work in publishing outstanding issues of the Newsletter.

The Sugar Industry Research Institute has published and distributed the Newsletter without cost to the Society and deserves our thanks and appreciation.

Dr. R. Breaux, Research Agronomist, USDA, Sugarcane Field Station, Houma, Louisiana, has agreed to be Editor for the next three-year term, during which time the publication will be sponsored by the USDA Sugarcane Field Station, Houma.

A REVIEW OF MECHANICAL HARVESTING AND ITS EFFECT ON SUGARCANE QUALITY

By A. G. De Beer

From papers submitted to ISSCT Congresses over the past 12 to 15 years, it is clear that the emphasis has shifted from problems involved in implementing mechanical harvesting systems on estates not prepared for this, to a much more thorough look at the effect of the machines on the product delivered to the mill. It is obvious that smaller profit margins are forcing sugarcane and sugar producers into a more critical evaluation of machine performance. For this ISSCT Congress contributions on this aspect of sugarcane production have been submitted from countries such as Australia, Barbados, Brazil, Cuba, Iraq, Peru, South Africa and the United States of America. A number of countries are interested, for different reasons, in harvesting sugarcane without prior burning. Serious concern is thus developing about the capabilities of mechanical harvesters to handle green cane.

This paper will review some of the data published since 1969 on mechanical harvesting and cane quality. Contributions submitted to this Congress are also included.

FIELD EFFICIENCY

First reports on machine output received from countries other than Australia, presented a very poor picture. It was, however, soon appreciated that properly prepared fields were essential if acceptable performances were to be obtained from machines such as chopper harvesters. Papers published in Jamaica[37] and Mauritius[22] indicated that field efficiencies of about 40% could be expected. Twenty-five choppers in the French West Indies [12] gave an average field efficiency of 45%. In South Africa[11] it was established that while actual pour-rates were 60 t/h or more, productivity averaged only 20 t/field hour. Even under ideal conditions, 10% of the total field time was lost when turning on the headlands. Of course, factors such as field layout and availability of infield cane transport will also affect field efficiency. Under good field and management conditions, as they obtain in Australia, field efficiency can be as high as 60%.

EXTRANEOUS MATTER

Increased amounts of extraneous matter will adversely affect haulage payloads, mill throughput and sugar recovery. Clayton and Whittemore[5] reported in 1969 that each one percent of trash content resulted in a loss of 1,5 to 2,0% in

the value of the sugar produced. South African tests[32] at two mills showed that extraneous matter decreased the crushing rate by 2,2 to 3,0% for every additional 1% of trash (leaves) % cane. Tops did not adversely influence the rate of cane throughput. The effect of trash on sucrose % cane is illustrated by the fact that if clean cane contains 13% sucrose, additions of 5, 10 and 20% trash will reduce this value to 12,35; 11,70 and 10,40% respectively. From a laboratory investigation of the effects of trash it was concluded that both tops and leaves had pronounced adverse effects on juice purities and clear juice quality. In addition, the presence of dead leaves reduced pol extraction. All these effects were found to increase linearly with extraneous matter contents up to 30%[33].

The total extraneous matter content will largely be determined by field conditions such as variety, degree of lodging and wetness of the crop. Various studies [6, 8, 9, 10, 13, 14, 23, 38] have shown extraneous matter contents of chopper-harvested cane to vary from 6 to 17%, compared to those of hand-harvested cane of 3 to 7%.

Compared to manual cutting and push-pile loading, chopper harvesters, nevertheless reduce substantially the quantity of soil delivered with the cane[34]. In Brazil a reduction in mineral matter of three times, to 0,8%, was recorded in one study[14] while in another[38] soil content ranged from 0,1 to 0,3% for chopped cane as compared to 0,5 to 3,1% for mechanically-loaded cane. Other figures quoted varied from 1,3 to 0,6% for three different choppers tested in Brazil[29]. Australian researchers point out that the amount of loose soil recovered from a sample is generally much less than 50% of that recoverable when washing the billets carefully[21]. Cutting below ground will reduce the loss of millable cane in lodged conditions, but will increase the dirt content.

Using an ashing-technique to analyze 340 samples of push-piled mechanically loaded cane from eight different loaders over a three month period in South Africa, the average soil content was found to be 5,2% d.m., but daily averages periodically exceeded 10% d.m. with individual samples sometimes exceeding 20% d.m. Over the same period, in the same area, 22 samples of chopper harvested cane had a soil content of 2,0% d.m.[35].

Tops frequently comprise 70% of the total extraneous matter in chopper harvested cane[17]. The problem is that if, due to recumbancy, the external topper does not remove the tops, there is little chance of their being removed later. If the extractor fans are adjusted to remove these tops, too high a percentage of billets will also be lost in the process[40].

By improving the quality of the burn during poor weather conditions, through the use of chemicals such as Gramoxone, the total trash content of mechanically-harvested cane can be substantially reduced. This was found to be so in Iraq where

S.W. Baxter, personal communication

trash content was reduced from 13,7 to 2,4%[3].

The Bureau of Sugar Experiment Stations in Australia has developed a convenient method to sample the cane delivered by a chopper harvester[18]. A portable, light-weight chute is attached to the back of the haulout bin or trailer. Samples are taken by signalling the haulout driver to move forward briefly so that the harvester discharges directly into the chute. A bag attached to the bottom of the chute then catches the sample. This sampling method allows the harvester to cut without any interruptions, and the sample is likely to be quite representative.

FIELD LOSSES

Field losses of sugarcane due to chopper harvesting consist of cane left behind in the field and losses of juice and cane fragments so small that they cannot be gleaned (invisible losses). Cane left behind can easily be determined by the careful gleaning of marked-off plots immediately following harvesting. Typical values for this part of the cane loss vary from 2 to 10%[10, 26, 34, 41].

Invisible losses are more difficult to determine, especially under actual operating conditions. A survey of invisible losses was made when using six chopper harvesters in Florida in 1974.* This followed on reports from Australia[39] that losses were 19% and up to 30% when pre-weighed cane was fed through harvesters. In the Florida study, harvesting mechanisms and extractor fans were operated at normal speeds and pre-weighed cane was fed through the machines. After the tests, all cane found inside the machine was added to that which dropped out of the harvester. There was still a shortfall of 3,2%, which was regarded as an invisible loss, probably due to the disintegration of billets and lost juice. According to a Mexican study carried out in 1975[7] two chopper harvesters delivered 78% of available millable cane as compared to 94% from manual cutters. Both "cane left behind" and "invisible losses" were probably included in these figures.

A 1976 study at Rio Grande Valley Sugar Growers,[31] comparing hand cutting with a chopper harvester, indicated that little, if any, juice was lost in the mechanical harvesting operation. However, when testing eight different models of chopper harvesters in 1977[28] in a field averaging 133 t/ha, it was found that 15% of the pol available after burning was lost during the harvesting operation. This loss was made up of 1% pol recovered with the trash, 10% lost in scrap left behind in the field and 4% an undetermined or invisible loss. These values were determined by comparing the pol % cane and fiber of hand cut samples and the net cane component of the gross cane delivered by the machines.

During 1976 it was reported in Hawaii[19] that the extraction fans of a specially-built chopper harvester removed 2,0 tons recoverable pol/ha from 261 tons of sugarcane/ha. South African tests,[9, 10, 36] based on direct comparisons

* *Jose E. Clayton, personal communication*

of millable cane delivered by machine and by manual cutting, gave invisible losses due to chopper harvesting of 4 to 15% in excess of those due to manual cutting. The lower values were found with well maintained machines, while the higher values were for machines obviously in need of attention.

As a comparison, a South African study of the results from 243 samples taken on three different estates, showed a loss of millable cane due to hand cutting and mechanical loading of 3,0%. This was reduced to 1,7% with subsequent manual gleaning[10].

A different approach to establish losses during harvesting was followed in Brazil, where the effects of two chopper harvesters were compared with those of manual cutting and mechanical loading[15]. In this case the main parameter studied was the ton pol/ha delivered at the mill. Samples were taken at the mill, shredded and the juice expressed. The manually harvested treatment gave the best values for pol % cane, fiber % cane, juice % cane, reducing sugar % juice and juice purity. Manually cut cane also resulted in higher tonnages of cane and pol harvested per ha. For the variety CB41-76, for example, manual cutting resulted in 13,8 ton pol/ha compared to 9,3 and 12,4 ton pol/ha respectively for the two harvesters.

According to an Australian harvester manufacturer, efforts to improve the efficiency of extraction by increasing air flows have produced unacceptable cane losses due to millable cane pieces passing through the extractors. A compromise setting, resulting in a 3% cane loss, is normally used[40].

BILLET QUALITY

Most work on billet quality has been done in Australia. In 1977 the BSES commenced performance testing of harvesters with a view to establishing *inter alia* the effect of different machines on billet length and billet damage. Procedures to grade billets into "sound", "damaged" and "mutilated" classes have been proposed. Results showed that the speed of harvesting had very little effect on billet quality, provided the machines were well maintained. Lodged crops, on the other hand, reduced the proportion of sound billets. Massey-Ferguson chopping mechanisms gave the most consistent supply of sound billets and the least variability in length [17, 25]. Toft chopper knives required frequent replacement but in these machines this is a relatively easy and quick operation. If the chopper blades of Claas harvesters were not sharpened for 23 hours, the proportion of sound billets fell from 60% to 12%. Typically, 50 to 80% of billets cut by the machines mentioned were classed as having well cut ends.

GREEN CANE HARVESTING

Harvesting green cane in Texas in 1977 with eight different chopper har-

vesters resulted in a reduction of 68% in pour rate compared to that for burnt cane at 66 t/ha[28]. Australian researchers[17] found that a Claas 1400, MF205, Toft 4000 and a Toft 6000 were all capable of harvesting green, erect crops of Q90 with extraneous matter levels similar to those obtained in burnt cane. Pour rates were, however, reduced by 30 to 40% compared to those for burnt cane. Another Australian study[25] showed that the efficiency of trash removal was largely dependent on the quantity of trash present in the field. Chopper harvesters removed a higher percentage of the trash contained in green than in burnt cane. It is interesting to note that, compared to burnt cane, green cane harvesting will often result in a larger percentage of tops being removed. This is due to the lodging effect of burning which may place a large number of tops beyond the reach of mechanical toppers[25, 30].

The performance of a number of Class 1400 harvesters was studied recently in Texas while harvesting 812 ha and 3,687 ha of green and burnt cane respectively[30]. Green cane harvesting increased both the trash content and the amount of cane left behind in the field. In comparison with burnt cane, green cane harvesting sustained a loss of 7,4% of sugar recovery, even though the quality of the juice was superior. Green cane harvesting increased production costs by 9,2% through reducing harvester, transport and milling efficiencies. It was concluded that with the present returns for sugar, green cane harvesting by chopper harvesters was not economically justifiable.

CURRENT RESEARCH INTO HARVESTER DESIGN

In addition to the development work being undertaken as a matter of course by harvester manufacturers, various research organizations are investigating basic machine component performance requirements in an effort to improve cane quality and harvesting capabilities and to reduce power requirements.

In Cuba it was discovered that for a particular machine configuration, the loss of cane through cleaning fans was not influenced by variations in feed rates. The power consumption of cleaning mechanisms was directly proportional to the initial extraneous matter content and it was affected more by the amount of cane passing through axial fans than by an equivalent mass of removed extraneous matter. Trash removal efficiency remained almost constant, with only a slight reduction as feed was increased[2]. The effect of chopping mechanisms on cane and juice losses has been studied by means of high-speed photography[27], and mathematical models are being developed to evaluate topper effectiveness[24]. A relationship between cane yield and extraneous matter content of the harvested sample has been established, indicating that top and total trash content decrease from 9% to 6% and from 12% to 4% respectively as the yield increased from 107 to 158 t/ha[1]. Pendulum cutting devices are used in Brazil to study the effect of knife speed, cutter geometry and the sharpness of cutting edges on the power required to cut through cane. One conclusion was that relatively blunt base cutter blades require three to six times as much power as does a sharp hand-held cane knife[4].

A REVIEW OF CANE DETERIORATION AND RELATED PROCESSING PROBLEMS

By D. H. Foster

This review does not pretend to be an exhaustive examination of the sugar industry literature relating to cane deterioration and the subsequent effects on processing. It tends to emphasize the factors which seem important in the writer's experience and is biased towards the experiences and solutions to problems obtained under Australian conditions. The writer's objective has been to present an introductory statement for this ISSCT panel discussion and it is hoped that shortcomings can be remedied by contributions from participants with more varied experience.

In discussing cane deterioration and subsequent processing problems it is essential to note that deterioration which is always time dependent can be minimized by establishing an efficient and well scheduled cane transport system. It is also desirable to roster harvesting operations to extend over the greatest possible time in a daily cycle. This also reduces the capital cost of transport equipment when transport containers are used for storage purposes. A well integrated harvesting and transport operation is in general, not only the least costly but also provides cane with a minimum of deterioration.

A great deal has been published over the years on deterioration in whole stick and chopped cane both burnt and green. In much of this work the cane has been cut for periods of 3, 7, 14 and even up to 20 days. Knowing as much as we do now about cane deterioration, the effects of these long delay periods should be only of academic interest, except in rare instances of strikes, bad weather, or other such catastrophe. In a well organized harvesting and transport system, all cane should be crushed within 24 hours of harvesting, yet there is only a small amount of information describing deterioration for periods less than this.

PRIOR TO HARVEST

Although deterioration of millable cane is generally considered as commencing from the time of burning, it can occur beforehand in green standing cane producing possible problems in processing. For example, sarkaran was identified by Bruijn[1] (1966) as a polysaccharide formed in cut cane following very long delays in transportation to the factory. A similar polysaccharide was implicated (Fulcher and Inkerman, 1976)[2] and subsequently identified (Blake, 1979)[3] in molasses derived from freshly-cut two year old cane. It has been suggested that this is a microbial polysaccharide which has entered through cracks in the internodes of the overmature cane. Difficulties in sugar boiling and high viscosity of syrups have sometimes been described by sugar mills in Queensland when processing this cane.

Attempts are being made to develop a laboratory heat transfer test to detect syrup abnormalities and to simulate the gumming of vacuum pan heating surfaces which has been experienced in mills.

Abnormal polysaccharides have also been found in canes infected with red rot (Foster, 1969)[4] and in apparently sound canes. These were sufficient in quantity to give up to 1600 ppm on Brix by the "dextran haze" test. However, insubsequent hydrolysis of crude alcohol precipitates from such canes, glucose galactose and mannose were found to be present. It appears that these polysaccharides do not occur extensively. Whether they are removed in clarification or what effects they have on processing are unknown. Because of these occasional variations it is desirable to make control checks, using treatment with dextranase, when the haze test is being used to measure dextrans.

CANE FIRES

The severe damage done to the outer portions of cane sticks in a cane fire is not generally appreciated. It has been concluded (Foster, 1979)[5] that the outer one millimeter of a 25 mm diameter cane stick containing 15 per cent of the cane weight is held between 98° and 400°C for several seconds. More recent experiments have shown that in fierce fires 102°C is reached 1 mm below the surface and of course, this may extend further towards the center. The juice in the outer parenchyma and vascular bundles actually boils and perforates the epidermal tissue. While there must be an immediate sterilizing effect the plants own system for protection from microbial attack must be severely impaired in the epidermis. If juice can escape then surely microorganisms can enter. Little has been done to identify those organisms which infect through these perforations immediately after burning although McNeil and Inkerman (1977)[6] have identified a wide range of organisms in cane where harvesting had been prevented by heavy rain for 10 to 20 days after burning.

The high temperatures reached in the fire must also destroy appreciable sucrose and promote a number of other reactions, some of which are color forming. Reference is made here to the mode of sucrose degradation at high temperatures as described by Richards *et al.* (1979)[7] in another paper at this congress.

Colour is substantially greater in syrups from clean burnt cane than from clean green cane. Eight comparisons of clean green and burnt cane were made in which the cane was crushed and processed to syrup (Foster, 1979)[5]. Color of the

$$* \text{colour} = 1000 \,/\, (a_{420} - 2a_{720})$$

$$\text{where } a = \frac{A}{bc}$$

A = $-\log_{10}$ / at pH_7

b = cell length in cm

c = concentration in g/ml

syrup from burnt cane averaged 8570* as against 7390 from the green cane. Processing was carried out as rapidly as possible through to the clarification stage to minimize enzymic browning which has been demonstrated by Gross and Coombs (1976)[8] Of course, large amounts of extraneous matter in green cane may outweigh the effect of burning and promote increased color as shown by Sloane and Rhodes (1972)[9] .The point to be emphasized is that burning causes a serious deterioration of cane and ideally it should be avoided. In practice, harvesters are not adequate to produce clean green cane at a sufficient rate to be economically acceptable and this is an area that warrants substantial agricultural engineering research.

The act of burning not only destroys sugar to an extent which varies with the severity of the fire, but also pre-disposes the cane to deterioration while waiting to be harvested and during the subsequent period between harvesting and crushing. Five to seven per cent more recoverable sugar has commonly been observed in matched samples of green versus burnt cane harvested at a northern mill in Australia (Foster, 1979)[5] .The difference is partly due to the effect of the cane fire and the subsequent deterioration but also to a dilution effect due to the well known ability of burnt cane to take up water and increase in weight after burning. In the experiments described above, harvesting was carried out in the day after burning when weight increase had been generally less than one per cent. However, water uptake can be up to four per cent as noted by Young (1962)[10].

Results of processing 2000 tons of green cane which was matched as closely as possible with 2000 tons of burnt cane are shown in Table I (Foster, 1979)[5]. The green cane was chopper harvested and crushed on one day, then the matched cane was burnt that evening and harvested and processed on the following day. Delays between cutting and crushing averaged about 8 hours and the burnt cane contained seven per cent extraneous matter as opposed to eight per cent in the green cane. The CCS (recoverable sugar) in the green cane was 15.35 per cent compared with 14.6 per cent in the burnt cane. The results in Table I are the averages of many analyses on samples taken through an eight hour processing period. They show slightly less color and much less ethanol in the products from the green cane. The reduced level of ethanol has interesting implications for treatment of effluents which contain surplus water distilled off at the evaporators (Blake and McNeil, 1978)[11]. Syrup from burnt cane was of a slightly lower purity than that from green cane. If the differences in recoverable sugar were due chiefly to microbial deterioration, much greater purity differences would be observed. Possibly the cane loses substantial amounts of sugar in juice which is expelled during the cane fire and maybe some is converted to insoluble char. Careful measurements of weight changes in sticks have indicated little difference between green cane and cane 18 hours after burning. This may have been masked by juice losses being counteracted by water uptake.

TABLE I. Quality of juice and syrup from green and burnt cane

	Burnt	Green
Clarified Juice		
Turbidity 975 nm	15.2	9.6
Ethanol mg/1	270	52
Syrup		
Purity $(\frac{\text{sucrose}}{\text{dry sub}})$	91.25	91.45
Ash	1.84	1.76
Reducing sugars	1.30	1.23
rs/ash	.706	.699
Filterability (Nicholson test)	57	63
Colour 420 nm	10420	10030
Dextran	0	0

A similar observation has been made by Holder and De Stefano (1977)[12]. They reported yields of sucrose five per cent greater in cool burnt cane as compared with hot burnt cane and they also found little difference in purity of juice.

BURNT CANE STANDING IN THE FIELD

It is difficult to lay down definitive rules for predicting rates of deterioration for burnt standing cane since they depend on the quality of the cane and weather conditions. For example, greater attention must be given to minimize the time between burning and cutting in northern tropical areas of Queensland than on the sub-tropical coast. In the former, it is common practice to burn cane on the evening of one day and to harvest completely on the next day. To avoid deterioration by standing cane over week-end periods when harvesting and milling cease for a two day period, some farmers burn less than their quota of cane on Thursday and complete their delivery to the mill with a number of bins of freshly-cut green cane.

Fulcher and Inkerman (1974)[13] have found 1900 ppm on Brix of dextran in sound-standing burnt cane after a period of only four days during the hot part of the crushing season in north Queensland. This is evidence of earlier microbial infection. Investigations in South Africa (Wood and Du Toit, 1972)[14] and in Mauritius (1974)[15] seem to indicate negligible deterioration in burnt standing cane for one day after burning, but purity was falling and reducing sugars increasing after

syrup from burnt cane averaged 8570* as against 7390 from the green cane. Processing was carried out as rapidly as possible through to the clarification stage to minimize enzymic browning which has been demonstrated by Gross and Coombs (1976)[8] Of course, large amounts of extraneous matter in green cane may outweigh the effect of burning and promote increased color as shown by Sloane and Rhodes (1972)[9] .The point to be emphasized is that burning causes a serious deterioration of cane and ideally it should be avoided. In practice, harvesters are not adequate to produce clean green cane at a sufficient rate to be economically acceptable and this is an area that warrants substantial agricultural engineering research.

The act of burning not only destroys sugar to an extent which varies with the severity of the fire, but also pre-disposes the cane to deterioration while waiting to be harvested and during the subsequent period between harvesting and crushing. Five to seven per cent more recoverable sugar has commonly been observed in matched samples of green versus burnt cane harvested at a northern mill in Australia (Foster, 1979)[5] .The difference is partly due to the effect of the cane fire and the subsequent deterioration but also to a dilution effect due to the well known ability of burnt cane to take up water and increase in weight after burning. In the experiments described above, harvesting was carried out in the day after burning when weight increase had been generally less than one per cent. However, water uptake can be up to four per cent as noted by Young (1962)[10].

Results of processing 2000 tons of green cane which was matched as closely as possible with 2000 tons of burnt cane are shown in Table I (Foster, 1979)[5]. The green cane was chopper harvested and crushed on one day, then the matched cane was burnt that evening and harvested and processed on the following day. Delays between cutting and crushing averaged about 8 hours and the burnt cane contained seven per cent extraneous matter as opposed to eight per cent in the green cane. The CCS (recoverable sugar) in the green cane was 15.35 per cent compared with 14.6 per cent in the burnt cane. The results in Table I are the averages of many analyses on samples taken through an eight hour processing period. They show slightly less color and much less ethanol in the products from the green cane. The reduced level of ethanol has interesting implications for treatment of effluents which contain surplus water distilled off at the evaporators (Blake and McNeil, 1978)[11]. Syrup from burnt cane was of a slightly lower purity than that from green cane. If the differences in recoverable sugar were due chiefly to microbial deterioration, much greater purity differences would be observed. Possibly the cane loses substantial amounts of sugar in juice which is expelled during the cane fire and maybe some is converted to insoluble char. Careful measurements of weight changes in sticks have indicated little difference between green cane and cane 18 hours after burning. This may have been masked by juice losses being counteracted by water uptake.

TABLE I. Quality of juice and syrup from green and burnt cane

	Burnt	Green
Clarified Juice		
Turbidity 975 nm	15.2	9.6
Ethanol mg/1	270	52
Syrup		
Purity $(\frac{\text{sucrose}}{\text{dry sub}})$	91.25	91.45
Ash	1.84	1.76
Reducing sugars	1.30	1.23
rs/ash	.706	.699
Filterability (Nicholson test)	57	63
Colour 420 nm	10420	10030
Dextran	0	0

A similar observation has been made by Holder and De Stefano (1977)[12]. They reported yields of sucrose five per cent greater in cool burnt cane as compared with hot burnt cane and they also found little difference in purity of juice.

BURNT CANE STANDING IN THE FIELD

It is difficult to lay down definitive rules for predicting rates of deterioration for burnt standing cane since they depend on the quality of the cane and weather conditions. For example, greater attention must be given to minimize the time between burning and cutting in northern tropical areas of Queensland than on the sub-tropical coast. In the former, it is common practice to burn cane on the evening of one day and to harvest completely on the next day. To avoid deterioration by standing cane over week-end periods when harvesting and milling cease for a two day period, some farmers burn less than their quota of cane on Thursday and complete their delivery to the mill with a number of bins of freshly-cut green cane.

Fulcher and Inkerman (1974)[13] have found 1900 ppm on Brix of dextran in sound-standing burnt cane after a period of only four days during the hot part of the crushing season in north Queensland. This is evidence of earlier microbial infection. Investigations in South Africa (Wood and Du Toit, 1972)[14] and in Mauritius (1974)[15] seem to indicate negligible deterioration in burnt standing cane for one day after burning, but purity was falling and reducing sugars increasing after

deteriorated cane than those due to the presence of dextran alone.

If delays between cutting and crushing cannot be shortened sufficiently, other alternatives may be sought. Most of the occurrences of dextran and its associated deleterious effects would be largely eliminated if cane could be harvested green. This applies both to whole stick cane (Wood and Du Toit, 1972)[14] and to chopped cane (Ivin and Foster, 1977)[22]. Unfortunately, harvester development has not yet reached the stage where this is practical and economic in all crops. In particular, the harvesting rate is generally too slow when the requirement of a low level of extraneous matter is imposed. However, this is an option which has been chosen by some farmers in the hot and high rainfall section of the Queensland coast.

Finally, if no other alternative is available, one very effective method of overcoming most of the processing difficulties with *leuconostoc* infected cane is to use the enzyme, dextranase (Inkerman and James, 1976[28], Inkerman and Riddell, 1977[29]). This results in much improved rates of crystallization and improved molasses exhaustion. In addition, crystals are not elongated and better filterability results from improved clarification. However, the use of dextranase should be regarded only as a last resort when extraordinary events have seriously delayed cane deliveries.

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REPORT OF THE CHAIRMAN 1977-1980 STANDING COMMITTEE ON SUGARCANE DISEASES

By Claude Ricaud, Chairman

There has been a good participation of members in the activities of the Standing Committee during this three-year period, but as usual some have been more involved than others.

COMMITTEE MEMBERSHIP

Due to the retirement of several pathologists and the change in interest of others, there have been many changes in the membership of the committee. Most of these were decided at the meeting of the committee at the 16th Congress in 1977, a few other names have been added, following suggestions made later. Members who have shown no response to our letters have been deleted from our list. The inclusion of new members in order to cover as many important sugarcane areas as possible, particularly in South-East Asia and Latin America, should be discussed at the next Congress.

WORLD LIST OF SUGARCANE DISEASES

I wish to record the good response from committee members for the updating of the list. There have been few amendments in general except for smut and the rusts. It is the wish of the committee that the list be published in extenso in the proceedings, because of its importance as a reference.

SUGARCANE PATHOLOGISTS' NEWSLETTER

The flow of contributions to the Newsletter has been steady and its publication has been regular, twice yearly, since the last Congress, with an average of about 20 contributions for each issue. The distribution list was revised after a circular letter was sent around to recipients, not only to cut down on production and mailing costs, which are borne by the sponsoring body, but to ascertain that the Newsletter was meeting its objectives and was being sent to those directly interested in sugarcane diseases. There are now 250 recipients from 49 countries. However, to ensure rapid spread of information, a limited number of copies is sent by air. Senior authors of articles are included in this exclusive distribution and it is ascertained that each organization concerned with sugarcane research receives at least one copy by air.

We would like to thank the Mauritius Sugar Industry Research Institute for having sponsored the publication of the Newsletter for the last inter-congress period.

The editorship will pass to Dr. A. G. Gillaspie, Jr. for the next three years during which the Newsletter will be sponsored by the United States Department of Agriculture.

PUBLICATION OF BOOK ON SUGARCANE DISEASES

At the 1977 Congress, it was decided that consideration would be given to the desirability of publishing a new edition of the book Sugarcane Diseases of the World, Vol. I.

This project has been a major preoccupation of the committee during the last three years. Elsevier Publishing Co. is agreeable to undertake the publication of the book. An Editorial committee has been set up, consisting of the following:

C. Ricaud, Mauritius (Chairman)
B.T. Egan, Australia
A.G. Gillaspie, Jr., U.S.A.
C.G. Hughes, Australia

The editorial committee has come to the conclusion that a new version dealing with the major diseases of sugarcane could be more useful than just a revised edition of the old volume. This has had the approval of Standing Committee members. In the new version some of the chapters of the last book will be retained, with minor or major revision. Other topics in which considerable development has occurred will be completely rewritten by new authors. Some topics will be deleted altogether for inclusion in another edition of Volume II, the publication of which will be undertaken at a later date. Certain diseases which had been dealt with in Volume II, but which are now considered more important, will be included in the new version on major diseases.

The organization of editorial procedures have been finalized and authors are now being contacted definitely. It is hoped that the new book will be published in 1982.

AFFILIATION TO ISPP

At the last Congress it was also decided, that the ISSCT, through its Standing Committee, should become affiliated to the International Society for Plant Pathology. This affiliation has been sought and accepted. At the third international Congress for plant pathologists the objectives of such affiliation were discussed. Several other crop orientated groups of plant pathologists are affiliated to the ISPP which stimulates and co-ordinates international co-operation for work on plant diseases.

There is possibility to organize discussions sessions for the crop-orientated groups at the International Congresses organized by ISPP.

INCANDEX

The difficulties faced in maintaining the International Cane Disease Index (INCANDEX) had been raised by the previous Chairman of the Committee Proposals have been made by those responsible for its reorganization. These have been followed and printouts of new references stored have been published in the Sugarcane Pathologists' Newsletter, although not as frequently as it had been intended. The possibility of moving INCANDEX to an international computer network had been proposed but the project has not been pursued. We are thankful to the Colonial Sugar Refining Company who will continue to service the System; better computer facilities have been made available, which will improve information retrieval.

I should like to express my warmest thanks to all those who have assisted me during these three years.

GENERAL SECRETARY-TREASURER'S REPORT

It is a privilege to present the report of the General Secretary-Treasurer for the period from the XVI Congress to the business meeting held on February 11th, 1980.

MEMBERSHIP

For the period under review, our membership stands at 1988 coming from 76 countries including the host country, the Republic of the Philippines. Membership from the Philippines stands at 430.

Comparative figures for membership for the last five Congresses show the following:

YEAR	CONGRESS	HOST COUNTRY	MEMBERSHIP
1980	XVII	Philippines	1988
1977	XVI	Brazil	2584
1974	XV	South Africa	2081
1971	XIV	Louisiana	1558
1968	XIII	Taiwan	1156

ACTIVITIES DURING THE PERIOD UNDER REVIEW

Eight (8) issues of NEWSLETTERS or a total of 21,000 copies were circulated primarily to members from April 1978 to December 1979 with information on the XVII Congress activities, programmes, and other matters relevant to the Society.

At the plenary Session of the XVI Congress of the ISSCT held in Brazil, a Steering Committee for Constitutional Review was appointed and adopted (Resolution No. 4) "to study the present Constitution of the Society and recommend the required ammendments to bring it in line with present day requirements of the Society".

The following ten members were appointed and approved: Mr. O. W. Sturgess (Ghairman), Mr. R. Antoine (Secretary), Dr. T. G. Cleasby, Dr. D. T. Loupe, Dr. S. Paranhos, Mr. B. B. Ramaiah, Mr. C. B. Raymond, Mr. L. Rivas, Dr. K. Shoji and Dr. A. J. Vlitos.

The Steering Committee met on three occasions: from the 26th to the 28th of July 1978 in Manila, from the 25th to the 29th of June in London and on the 1st of February 1980 in Manila.

THE ISSCT XVII CONGRESS

953 registered delegates and 130 wives from 65 countries and with 38 regional divisions, including three new divisions (Bangladesh, Malaysia and Peru) were represented at the Congress.

Out of a total of 339 technical papers received from 36 countries, 256 were accepted for presentation at the Congress. These are classified into Sections as follows: Agronomy – 35, Plant Physiology – 33, Agricultural Engineering – 27, Cane Breeding – 30, Plant Pathology – 35, Entomology – 23, Factory Engineering – 10, Processing – 35, and By-Products – 28. A maximum number of only 35 papers were accepted in each Section (as the case may be) for presentation at the corresponding Section.

As an innovation to the XVII Congress, a General Plenary Session was introduced to commence preceeding each day's technical sessions from February 05 to 09, 1980 with special guest speakers who were invited to speak on special subjects. This innovation was very highly commented on.

The following were the special guest speakers:

1) February 05
"High Fructose Syrups: The Competition to Sugar"
Guest Speaker: Mr. Donald E. Nordlund
Chairman, President & Chief Executive Officer
A. E. Staley Mfg. Company
Decatur, Illinois, U. S. A.

2) February 06
"The Politics of Sugar"
Guest Speaker: Mr. William E. Miller
Executive Director
International Sugar Organization
London, England

3) February 07
"The Use of Sugar"
Guest Speaker: Mr. John M. Mount
Vice-President & Director of Purchasing
The Coca-Cola, Company, U.S.A.
Atlanta, Georgia, U.S.A.

4) February 08
"The Sugar Industry In A Changing Economic Climate"
Guest Speaker: Dr. Helmut Ahlfeld
Managing Director
F.O. Licht GmbH
Ratzeburg, Fed. Rep. Germany

(Due to unavoidable circumstances with regards to plane connections, Dr. Ahlfeld was unable to be present at the Congress. Mr. Donald K. Luke, Jr., Editor, SUGAR y AZUCAR graciously consented to deliver Dr. Ahlfeld's speech).

5) February 09
"Some Economic Implications of Power Alcohol"
Speaker: Dr. Michael C. Bennett
Director of Technical Development
Tate & Lyle Agribusiness Limited
England

Panel discussions of the standing Committees on: 1) Harvesting and Cane Handling, headed by Dr. Gerard de Beer and 2) Germplasm and Cane Breeding, headed by Dr. Don Heinz were had. A report of the standing Committee on Sugarcane Diseases was made by Chairman Claude Ricaud. Separate reports on these are printed elsewhere in this volume of the Proceedings.

Symposia on Energy were held on the subjects: 1) "The Growing of Sugarcane for Energy" by Dr. Roger P. Humbert,[2] "Sugar as Biomass" by Dr. A. G. Alexander (read and discussed by Dr. Kenneth Parker, and 3) "The Tate and Lyle Sucrose Ester Process" by Mr. F. K. Imrie. The report of the first subject is also printed elsewhere in this volume of the Proceedings.

Following exhaustive deliberations at the three meetings of the Steering Committee, the "Proposed Constitution of the International Society of Sugar Cane Technologists", which embodied the recommendation of the Steering Committee, was presented at the meetings of the Administrative Committee (composed of Regional Vice-Chairmen). Some ammendments were presented, accepted and approved and the "Proposed Constitution" was passed unanimously.

After the adoption and/or ratification of the new Constitution at the Business Meeting held on February 11th at 10:00 A.M., the former Regional Vice-Chairmen (now re-styled Councilors) took timeout from the meeting and met to elect the ten (10) members of the Board of Trustees as provided for in the new Constitution (Article V).

The following were elected to serve for a period of six years:

Robert Antoine
Carlos Bell Raymond
Denver T. Loupe
August John Vlitos
Gerald Thompson

The following were elected to serve for a period of three years:

Fernando Z. Cordovez
Kobe Shoji

Owen Surgess
Luis Rivas
J.L. du Toit

The 10 members of the Board of Trustees elected Mr. Owen Stuurgess and Mr. Robert Antoine as Chairman and Secretary, respectively.

The membership dues were then fixed as follows:

Individual Member	:	US $ 15.00
Affiliated Member	:	US $100.00
Institutional Member	:	US $100.00
Corporate Member	:	US $750.00

All classes of membership (including Honorary Members), except individual member, will receive a copy of the Congress Proceedings (Article VII, Clause 11 of the new Constitution).

MEMBERSHIP DUES

The amount of ₱737,738.55 was collected from the members of the XVII Congress. All Bank charges were paid by the Philippine Sugar Commission (PHILSUCOM).

FINANCE AND PROPERTY REPORT

The ISSCT Custodian, Mr. D. J. Dougherty, submitted the following report as of January 1st, 1980:

Savings Account (04-1701-5)
Bank of Hawaii - - - - - - - - - - - - - - - - - $20,041.91*

*Includes $4,831 of previously committed funds which were returned to the General Funds of ISSCT by the Germplasm Expedition.

25 copies of the XVII Congress Proceedings will be sent to the Custodian for sale and in addition, two (2) copies will be sent for the permanent file.

Mr. Dougherty was reappointed to continue as the ISSCT Custodian. On behalf of the Society, I would like to express my sincerest thanks and appreciation for his work well done.

HOST TO HOLD THE XVIII CONGRESS (1983)

Cuba won the bid to host the next Congress to be held in Havana on February, 1983. This was approved by acclamation at the Plenary Session

(Business Meeting) on February 11, 1980.

No country has signified to host the Post-Congress Tour in 1983.

AWARDS

PLAQUES OF APPRECIATION were awarded to some officers of the XVII Congress for having contributed their valuable time and efforts on the review and evaluation of technical papers and the translation of the Abstracts from English to Spanish.

Awarded were the General Chairmen for Agriculture and for Factory, the Sectional Chairmen, the Filipino Vice-Chairmen, and the Spanish-Speaking Vice-Chairmen.

APPRECIATION AND THANKS

I would like to express my deepest appreciation and gratitude to the Philippine Sugar Commission (PHILSUCOM), especially to its Chairman, Ambassador Roberto S. Benedicto (General Chairman, ISSCT XVII Congress) for the full support, patience, understanding and cooperation given to me and to the members of the Congress. Organizing Committee.

My sincerest thanks and appreciation to the General Chairmen for Agriculture and for Factory, to the Sectional Chairmen, to the Filipino Vice-Chairmen, and to the Spanish-Speaking Vice-Chairmen for their patience, kind attention and cooperation with the Secretariat, with the Executive Committee and with the Congress Organizing Committee. Each of them has contributed his valuable time and efforts to the service of the Society and without their help and cooperation the XVII ISSCT Congress would not have been a big success.

And, I would also like to express my sincerest thanks and gratitude to those, who in one way or another, helped to make the Congress a success as it was.

It was an honor and privilege to serve the Society since September 1977.

XVII ISSCT CONGRESS

REPORT OF THE RESOLUTIONS COMMITTEE

RESOLUTION NO. 1

WHEREAS, the official opening of the XVIIth ISSCT Congress in Manila was made an especially memorable occasion by the attendance of and the addresses given by His Excellency Ferdinand E. Marcos, President and Prime Minister of the Philippines, and Madame Imelda Romualdez Marcos, First Lady, Minister of Human Settlements and Governor of Metro Manila, it is resolved that the sincere thanks and appreciation of all delegates should be conveyed to the President and the First Lady, with an assurance that our stay in the Philippines has been both profitable and enjoyable.

RESOLUTIONS NO. 2

WHEREAS, the XVIIth ISSCT Congress in Manila has been an outstanding success; and

WHEREAS, the organization of the Congress has been excellent; and

WHEREAS, the delegates have enjoyed unforgettable hospitality in the Philippines; It is resolved that a rising vote of thanks be accorded to the General Chairman, Ambassador Roberto S. Benedicto; the General Vice-Chairman Jaime C. Dacanay; the General Vice-Chairman Santiago Z. Ureta; the General Vice-Chairman Edgardo Yap; the General Secretary-Treasurer, Mr. Carlos Bell Raymond; the General Vice-Chairman and Executive Officer of the Philippine Sugar Commission, Jose A. Unson; the many Philippine Officials who served at the Congress; and also to the Philippine people, whose friendly reception at all times made this one of the happiest Congresses that the ISSCT has ever held.

RESOLUTIONS NO. 3

WHEREAS, the delegates to the XVIIth ISSCT Congress have gained a great deal from visiting various estates, mills and institutes in the Philippines, it is resolved that a strong vote of thanks should be accorded to:

i. AIDSISA
ii. the Hawaiian Milling Company
ii. the Victorias Milling Company
iv. Central Azucarera Don Pedro

v. Canlubang Sugar Estate
vi. Central Azucarera de Tarlac
vii. the University of the Philippines at Los Banos
viii. the International Rice Research Institute, and
ix. the Ministry of Tourism

It is further resolved that a special vote of thanks should be accorded to the Victorias, Central Azucarera Don Pedro and Canlubang Estates for the outstanding luncheon hospitality shown to delegates during the pre-congress tours, and to delegates' wives at Central Azucarera de Tarlac during the Congress.

RESOLUTIONS NO. 4

WHEREAS, the XVIIth ISSCT Congress in Manila has been an outstanding success, it is resolved that the Organizing Committee should be highly commended on the introduction of the principle of having General Plenary Sessions to commence proceedings on each day of the Congress, and also on the competence of the speakers who were invited to address the assembled delegates at these sessions.

It is further resolved that the host country of future ISSCT Congresses should be encouraged to maintain this valuable innovation.

RESOLUTIONS NO. 5

WHEREAS, death has removed a number of members of our Society from our midst during the period since the XVIth Congress was held in Sao Paulo, it is resolved to express our sorrow on their passing, to extend our sympathy to their families, and to show our respect by standing and observing a moment of silence.

RESOLUTIONS NO. 6

WHEREAS, there is an increasing number of member nations of the ISSCT which are French-Speaking, it is resolved that in the future the French language shall receive privileges similar to those now given in the Society of the Spanish language. This implies that the Summary of each paper presented at a Congress shall be translated into French, and that a French-speaking Vice-Chairman shall be appointed for each Section.

RESOLUTIONS NO. 7

WHEREAS, many delegates who attend ISSCT Congresses do not speak English,

it is resolved that the Organizers of future Congresses be required to provide simultaneous translations of the proceedings at both the Plenary and Technical Sessions into Spanish and French.

RESOLUTIONS NO. 8

WHEREAS, life membership of the Society may be conferred on members who have served the Society with distinction, it is resolved that this high honour shall now be conferred on

MR. CARLOS BELL RAYMOND of the Philippines.

Persons previously honoured with life membership are as follows:

E. V. Abbott (Louisiana)
G. Arceneaux (Louisiana)
Louis Baissac (Mauritius)
H. F. Clements * (Hawaii)
K. Douwes Dekker (Spain)
J. L. du Toit (South Africa)
A. G. Gallardo * (Mexico)
C. O. Grassl (U. S. A.)
E. Hugot (Reunion)
H. W. Kerr (Australia)
N. J. King (Australia)
C. L. Locsin (Philippines)
G. P. Meade * (Louisiana)
H. Morganti (Brazil)
J. M. Paturau (Mauritius)
C. E. Pemberton (Hawaii)
D. Smith (Puerto Rico)
O. Wiehe * (Mauritius)

RESOLUTIONS NO. 9

WHEREAS, it has become traditional for the organizers of an ISSCT Congress to keep delegates informed about current events during the Congress by means of a daily newsletter, it is resolved that the organizers of future Congresses be requested to maintain this tradition.

RESOLUTIONS NO. 10

WHEREAS, it is deemed advantageous to provide technologists in all sugarcane growing countries with information from and concerning the ISSCT during the period between successive congresses; and

* Deceased

WHEREAS, the publication of general newsletters by the host country of the impending congress, the Sugarcane Breeder's Newsletter, the Sugarcane Pathologists' Newsletter and the Sugarcane Entomologists Newsletter, fulfill this function only to a limited extent; and

WHEREAS, the cost of publishing the Proceedings of a Congress is becoming prohibitive and alternative means of publication might therefore be warranted; It is resovled that the trustees of the Society be requested to report to the XVIIth ISSCT Congress on the feasibility of using existing journals concerned with sugarcane and cane sugar as official vehicles for publishing and reporting some or all of the information and material concerning the Society and its deliberations.

RESOLUTIONS NO. 11

Standing Committee on Germplasm and Breeding

WHEREAS, the Standing Committee on Germplasm and Breeding has met and deliberated at the XVIIth ISSCT Congress, it is resolved on the recommendation of this Committee to acknowledge with thanks the contributions of the United States Department of Agriculture, through the Science and Education Administration, and the Government of India, through the Coimbatore Breeding Station, in maintaining the two world collections of sugarcane, and in duly distributing clones from the collections to requesting institutes. It is further resolved that the membership of the ISSCT should extend its sincere thanks and appreciation to the Mauritius Sugar Industry Research Institute for editing, publishing and distributing the Plant Breeders Newsletters during the past three years.

RESOLUTIONS NO. 12

Standing Committee on Mechanical Harvesting and Sugarcane Quality

WHEREAS, much interest was shown at the XVIIth ISSCT Congress in all papers related to mechanical harvesting and field mechanization; and

WHEREAS, the discussions which followed the presentation of these papers was always lively; and

WHEREAS, the response of delegates to the panel discussion on mechanical harvesting and cane quality was considerable; It is resolved that the Standing Committee on Mechanical Harvesting and Sugarcane Quality should continue

with its activities as outlined in Resolution No. 7 of the XVIth Congress, with provision for the Chairman to increase the membership of the Committee if necessary; and

WHEREAS, the two bibliographies published by the South African Sugar Association Experiment Station were well received by members, it is also resolved that this institute be requested to update the bibliographies before the next Congress; and

WHEREAS, the two review papers which were presented at the panel discussion on Mechanical Harvesting and Cane Quality were very useful contributions;
It is resolved that the organizers of the XVIIth ISSCT Congress should be requested to incorporate these in the official proceedings of the Congress.

RESOLUTIONS NO. 13

Standing Committee on Sugarcane Diseases

WHEREAS, it was resolved at the XVIth ISSCT Congress in Sao Paulo to investigate the need for a new edition of the volume entitled "Sugarcane Diseases of the World: Volume I"; and

WHEREAS, this resolution has been carried out, it is now resolved that a new version of the book should be prepared with the following provisions:

i. that Messrs. B. T. Egan (Australia), A. G. Gillaspie (USA), G. C. Hughes (Australia) and C. Ricaud (Mauritius, Chairman) should serve as an Editorial Committee;

ii. that Dr. S. Flores (Mexico), should provide Spanish summaries; and

iii. that the possibility of including French summaries of chapters will be investigated; and

WHEREAS, the Mauritius Sugar Industry Research Institute, through the services of Dr. C. Ricaud as Editor, was published and distributed the Sugarcane Pathologist's Newsletter bi-annually since the last Congress, it is resolved that the ISSCT should express its grateful thanks for the services rendered; and

WHEREAS, the United States Department of Agriculture will sponsor the newsletter from 1981 to 1983 through the services of Dr. A. G. Gillaspie as Editor, it is resolved that the ISSCT should express its grateful thanks for services to

be rendered; and

WHEREAS, the CSR Company of Sydney, Australia, continues to maintain the international computer index of literature on sugarcane diseases (INCANDEX); and

WHEREAS, the same Company continues to maintain the ISSCT collection of slides on sugarcane diseases; it is resolved that the ISSCT should express its grateful thanks for the services being rendered; and

WHEREAS, the Standing Committee on Sugarcane Diseases continues to serve a useful function, it is resolved that the Committee should remain in existence during the inter-Congress period from 1980 to 1983, under the Chairmanship of Dr. C. Ricaud, and with a membership reduced to five.

RESOLUTIONS NO. 14

WHEREAS, Mr. Paulo S. M. Botelho of IAA – Planalsucar in Brazil has generously offered to serve as Editor of and to publish the ISSCT Entomology Newsletter during the period from 1980 to 1983, it is resolved that this offer be accepted by the Society with thanks; and

WHEREAS, Mr. Armando de Costa Mendes has efficiently edited, and IAA – Planalsucar in Brazil has supported the publication of the Entomology Newsletter since the XVIth ISSCT Congress, it is resolved that these services should be acknowledged with thanks by the Society.

BUSINESS MEETING

REPORT OF THE STEERING COMMITTEE FOR CONSTITUTIONAL REVIEW

This Committee is composed of the following:

O. Sturgess (Chairman) – Australia and Pacific Region
R. Antoine (Secretary) – East Africa, Mauritius, Reunion
T. G. Cleasby – South Africa
D. T. Loupe – North America (Mainland)
S. B. Paranhos – South America
B. B. Ramaiah – India and Pakistan
C. B. Raymond – Philippines and Southeast Asia
L. Rivas – Central America and Carribean Region
K. Shoji – North America (Hawaii)
A. J. Vlitos – Europe

There was a common resolve that the existing objects of the Society should remain sacrosanct, with the important proviso that two additional objects were necessary to update the Constitution.

The additional objects which have been written into the revised Constitution allow for the formation of technical commissions and sections and for the affiliation of national and local societies of sugar cane technologists, with the international body.

The structure of the society was also amended by the creation of a Board of Trustees whose duties are to uphold the Constitution and assist or guide the Commissions in the international advancement of sugar cane technology.

The Committee was unable to graft these major changes into the existing Constitution, and therefore it recommends that this Constitution be rescinded and be replaced, by attached revised Constitution.

It is further recommended that the attached By-laws, which are consistent with the revised Constitution be adopted. These By-laws were prepared by reference to past resolutions, particularly those which have a direct influence on current practices.

The revised Constitution and the new By-laws have the unanimous support of the Steering Committee.

CONSTITUTION OF THE INTERNATIONAL SOCIETY OF SUGAR CANE TECHNOLOGISTS

ARTICLE I: *NAME AND OBJECTS*

Clause 1

The name of the Society shall be the International Society of Sugar Cane Technologists. The address of the Society shall be that of the General Secretary-Treasurer.

Clause 2

The objects of the Society shall be :

(a) to bring together sugar technologists to promote the technical discussion of field and factory problems of the sugarcane industry by means of Congresses, held as far as practicable every three years;

(b) to provide facilities for the observation of sugar production methods and related activities in the host country during the period of Congress and, under certain circumstances, in neighbouring countries;

(c) to foster the free and frank interchange of technical information;

(d) to form technical commissions and working groups to deal with the common problems of sugar cane technology;

(e) to promote co-operative research and development between the regions on topics to be specified by the membership or commissions, and to report regularly on these topics at Congresses or through appropriate media;

(f) to support worthy research projects, designed for the benefit of all;

(g) to provide a basis for the affiliation of national or local societies of sugar cane technologists with the Society.

------O------

ARTICLE II: *MEMBERSHIP*

Clause 1

Membership of the Society shall be open to all persons and organizations

involved in the study, application or dissemination of sugar cane technology.

The following classes of members shall be recognized:

(a) affiliated members: societies of sugar cane technologists with objects consistent with those of the Society;

(b) individual members;

(c) honorary life members;

(d) institutional members: research institutions, libraries, companies and other organizations, which are non-profit making and support the objects of the Society;

(e) corporate members: industrial and commercial organizations, which are associated with the sugar industry and which support the objects of the Society.

Clause 2

Honorary life membership may be conferred upon an individual member, who has rendered eminent service to the administration and/or has made an outstanding technical contribution to the Society.

(a) Honorary life members shall be recommended by the Trustees, elected by Council and announced at a plenary session of Congress;

(b) the number of honorary life members shall not exceed twenty-five and shall be selected from the present members of the Society;

(c) honorary life members, who shall not be required to pay dues and who shall have full status, shall be deemed to be fully paid up at all times.

Clause 3

Admission of members:

The forwarding of the name, address and dues to the General Secretary-Treasurer of an applicant, which qualifies for membership, shall constitute election to membership of the Society.

(a) Upon receipt of dues from an affiliated, individual, institutional or corporate member, the General Secretary-Treasurer shall forward the requisite certificate of membership;

(b) membership shall run from the end of one Congress to the end of the next Congress;

(c) membership shall lapse when dues have not been renewed after a period of one year following a Congress;

(d) should the General Secretary-Treasurer be in doubt as to whether an applicant qualifies for membership, then the application shall be referred to the Trustees.

(e) no member shall be admitted later than 30 days prior to the official opening of Congress.

———————O———————

ARTICLE III : *STRUCTURE OF THE SOCIETY*

Clause 1

The Society shall carry out its objects through the following structure:

(a) The Officers
(b) The Board of Trustees
(c) The Congress
(d) The Congress Organizing Committee
(e) The Council
(f) The Commissions

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ARTICLE IV : *THE OFFICERS*

Clause 1

The Officers shall be the Honorary President, the General Chairman, the General Vice-Chairman, and the General Secretary-Treasurer. The Honorary President, the General Chairman and General Secretary-Treasurer, shall be residents of the country in which the Congress is to be held.

Clause 2

At the final plenary session of Congress, the officers of the Society shall be nominated by the affiliated member, which has been awarded the next Congress, (the affiliated host member) and shall be accepted by members present. The Officers shall be members of the Society, except for the Honorary President who need not be a member.

Clause 3

In the event of an office falling vacant through death, resignation or other causes, the affiliated host member shall be empowered to fill such vacancy.

Clause 4

The General Chairman shall preside at meetings of the Council and Plenary Sessions of the Society. He shall perform duties provided for in this constitution and carry-out such functions as usually pertain to the Chief Officer of such a Society.

Clause 5

The General Vice-Chairman shall assist and co-operate with the General Chairman and General Secretary-Treasurer. He shall preside at the meetings of the Society in the absence of the General Chairman or at his request.

Clause 6

The General Secretary-Treasurer, during Congress, shall notify the appropriate members of meetings of Council, Commissions, Sections, and the Technical Committee. He shall execute such other duties as usually pertain to the office of Secretary. In addition:

(a) he shall be responsible for the safe-keeping of all current documents and at the conclusion of his term of office, forward to the custodian all such documents as are required for the permanent records of the Society;

(b) he shall receive the membership dues of the Society, keep a detailed account of these dues and submit, at a Plenary Session of Congress, a written report to Council, including the Custodian's report, on the activities of the Society during his term of office;

(c) he shall file reports and all other relevant documents on the activities of the Congress Organizing Committee during the term of his office and transmit these to his successor;

(d) he shall maintain liaison with the Board of Trustees, affiliated members, Councillors, Commissions and Sections.

Clause 7

The General Secretary-Treasurer shall prepare a list of names and addresses of members, which are paid-up at the opening of Congress, together with a list of names and addresses of Trustess, Councillors, Commissioners, and Sectional Chair-

men and arrange to have the lists published in the Proceedings of the Congress.

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ARTICLE V : *BOARD OF TRUSTEES*

Clause 1

The Council of the Society shall elect ten members to a Board of Trustees from nominations received. The Board shall appoint its Chairman and Secretary. No member shall occupy, at the same time, the positions of Councillor and Trustee.

Clause 2

A member of the Society, who is nominated as a Trustee, shall have the following qualifications and obligations:

(a) a record of distinguished service to the Society and the sugar industry in an administrative and/or technical capacity;

(b) have held membership for the last nine years, during which, at least, two Congresses will have been attended;

(c) be able to attend, not at the expense of the Society, meetings of the Board of Trustees;

(d) be prepared to resign as a Trustee if unable to attend two consecutive meetings of the Trustees;

(e) be able to attend all Congresses, which are held while the member is a Trustee;

(f) be proficient in the language of the Society;

(g) have held a senior professional post for at least six years.

Clause 3

Trustees shall be nominated by ten individual members who shall present to the General Secretary-Treasurer a written *curriculum vitae* in support of each nomination.

Clause 4

The duties of the Board of Trustees shall be :

(a) to ensure that the Constitution is upheld and the aims and objects of the Society are achieved;

(b) to review and recommend changes in the Constitution, as required;

(c) to report objectively to Council on the qualifications of affiliated members desirous of holding the next Congress, on the basis of adequacy of their local facilities and technical standards for that Congress;

(d) to assist and guide the Commissions in order to ensure that the technical standards of the Society are maintained;

(e) to be responsible to Council for the assets of the Society, and to ensure that such assets are used as determined by the Council;

(f) to appoint the Custodian;

(g) to assist the Congress Organizing Committee, if so requested;

(h) to report to Council on matters of interest to the Society.

Clause 5

A Trustee shall be elected by Council for a period of two Congresses but shall not serve for more than four consecutive Congresses.

Clause 6

A Trustee, who dies, resigns or ceases to be a Trustee for any reason, shall not be replaced until the next Congress.

Clause 7

The duties of the Custodian shall be as follows:

(a) to receive Proceedings, records and reports of Commissions, of which at least one copy shall be retained for reference and safe-keeping;

(b) to receive 25 copies of the Proceedings;

(c) to sell Proceedings surplus to each Congress at prices fixed by the Board of Trustees and credit the funds to the Society;

(d) to make payments from the Society funds as directed by Council;

(e) to see that the accounts are audited annually and forwarded to the General Secretary-Treasurer;

(f) to submit an audited statement of the Society's finance as defined in Article X for approval at each Congress;

(g) to carry out any other duties as directed by Council or by the Board of Trustees.

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ARTICLE VI : *THE CONGRESS*

Clause 1

The Congress shall be held as far as practicable every three years, attendance being restricted to members of the Society.

Clause 2

The purpose of the Congress is the advancement of sugarcane technology through the discussion of papers accepted by the Editorial Committee, symposia panel discussions, study tours, exhibitions, meetings of Council, Commissions, Sections, Committees and the Board of Trustees, Plenary Sessions and in any other way that Council may determine.

Clause 3

Arrangements for Congress shall be the responsibility of the Congress Organizing Committee.

Clause 4

An affiliated member desiring to host the next Congress shall so inform the Board of Trustees through the General Secretary-Treasurer, at least 30 days prior to the official opening of Congress giving details of its facilities and technical organization.

Clause 5

The place of the next Congress shall be decided by an absolute majority vote of Council

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ARTICLE VII : *CONGRESS ORGANIZING COMMITTEE*

Clause 1

The Congress Organizing Committee shall consist of Officers of the Society and any other members designated by the affiliated host member and which shall be responsible for making all necessary arrangements for each Congress.

Clause 2

If through unforeseen or unavoidable circumstances, it is not practicable to convene Congress at the agreed time and place, the Board of Trustees is empowered to select another affiliated member willing to act as host member for the next Congress, the decision to be made as soon as practicable. Under such circumstances, the Officers of the Society and the Congress Organizing Committee shall be appointed by the affiliated host member and endorsed by the Board of Trustees.

Clause 3

The Congress Organizing Committee is empowered to set up Sub-Committees, to which Congress responsibilities may be delegated.

Clause 4

The Editorial Committee comprising the Editor of the Congress Proceedings as Chairman and the nine Sectional Vice-Chairman, shall be appointed by the Congress Organizing Committee. The General Secretary-Treasurer shall be an *ex-officio* member.

Clause 5

The Editorial Committee, following discussions with and guidance from the Technical Committee, shall be responsible for the conditions of acceptance, refereeing and editing of all papers and the programming of papers into concurrent sessions, which shall not exceed four in number. The Editorial Committee shall ensure that:

(a) Papers, other than invited papers, shall be submitted by members;

(b) a condition for the presentation and publication of a paper at Congress, shall be either the attendance of the author, or if this is not possible, another member with appropriate technical qualification shall be responsible for the presentation and discussion of the author's paper;

(c) the technical programme for the Congress as approved by the Technical Committee, is implemented when practicable.

Clause 6

The Congress Organizing Committee shall inform members in a suitable way and in time, about the acceptance of papers and other arrangements for Congress. It is the duty of the Congress Organizing Committee, through the Editorial Committee, to ensure that all arrangements for the publication of the Congress Proceedings are carried out as rapidly and economically as possible.

Clause 7

The Congress Organizing Committee may issue, from time to time, Newsletters.

Clause 8

The Congress Organizing Committee shall determine for payment by all those members registered to attend Congress, a registration fee to cover the cost of preprints of all papers and convention expenses. The Committee shall also determine for optional acceptance, by registered members:

(a) the price of bound copies of the Congress Proceedings;

(b) a package fee or fees to cover accommodation, meals, tours, ladies programme and any other expenses.

Clause 9

The Congress Organizing Committee shall determine the methods of payment of Congress fees including Congress Proceedings, and charges for exhibition space made available to corporate members.

Clause 10

The Congress Organizing Committee may invite a limited number of guests to attend Congress.

Clause 11

The Congress Organizing Committee shall forward a free copy of the Congress Proceedings to all institutional, corporate, affiliated and honorary life members of the Society. Individual members, who elect not to attend Congress, shall be entitled to receive a copy of the Proceedings upon payment to the General Secretary-Treasurer of the price determined by the Congress Organizing Committee. Members may secure additional copies at the same price.

Clause 12

The price of the Proceedings to non-members shall also be determined by the

Congress Organizing Committee.

Clause 13

The General Secretary-Treasurer shall ensure that 25 copies of the Proceedings of each Congress shall be held for sale by the Custodian. The selling price to be fixed by the Board of Trustees and revenue from their sale shall be credited to the funds of the Society.

Clause 14

The language of the Society shall be English.

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ARTICLE VIII : *THE COUNCIL*

Clause 1

The Council shall consist of:

(a) The Officers;

(b) Representatives of affiliated members or, where there is no affiliated member, one Councillor for each country with 25 individual members of the Society; or, where a number of countries are grouped into a region with, at least, 25 individual members of the Society, one Councillor for that region;

(c) The Chairman of the Board of Trustees.

Clause 2

The functions of the Council are:

(a) to elect Trustees from the nominations received;

(b) to select the affiliated member to host the next Congress;

(c) to approve the appointment of Officers of the Society;

(d) to determine dues for each class of membership;

(e) to appoint a Committee to deal with Resolutions;

(f) to receive the report of the Technical Committee;

(g) to approve the report and audited accounts of the General Secretary-Treasurer;

(h) to consider the reports of the Board of Trustees.

Clause 3

One-half the members of Council shall constitute a quorum.

Clause 4

The Council shall be presided over by the General-Chairman and, in his absence, by the General Vice-Chairman.

Clause 5

Councilors shall be appointed by the affiliated member, country or region as they have 25 members but not later than 30 days prior to the official opening of Congress. A Councilor who is unable to attend a Congress shall notify the General Secretary-Treasurer of the member who will act in his stead prior to the opening of Congress.

Clause 6

The method of election to Council shall be decided by the affiliated member, or by the country or region with at least 25 individual members.

Clause 7

Voting on resolutions or by-laws shall be by a majority show of hands except when selecting the affiliated member to host the next Congress which shall require an absolute majority of vote.

Clause 8

A secret ballot shall be held to select the affiliated member to host the next Congress and may also be invoked when any Councillor requests it. In these circumstances, Council shall appoint scrutineers.

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ARTICLE IX : *THE COMMISSIONS*

Clause 1

The technical work of the Society shall be carried out by the Commissions,

which shall foster the study of particular branches of sugarcane technology through co-operative research and publications.

Clause 2

There shall be four Commissions covering Technical Sections as follows:

(a) Agricultural Commission : Agronomy, Physiology and Agricultural Engineering Sections;

(b) Biological Commission : Cane Breeding, Pathology and Entomology Sections;

(c) Factory Commission : Factory Engineering and Processing (including Refining) Sections;

(d) Products Commission : By-Products and Energy Sections.

Clause 3

The General Secretary-Treasurer shall request members on registration to attend a Congress to specify the Section of technical interest.

Clause 4

The Technical Committee shall be made up of the General-Chairman, the members of the four Commissions, the Editor of the Congress Proceedings, and the General Secretary-Treasurer.

Clause 5

The Technical Committee shall submit a review of the technical activities of the Society to Council. It shall also make recommendations to the General Secretary-Treasurer for transmission to the incoming Congress Organizing Committee on the technical aspects to be considered for the next Congress.

Clause 6

Each of the four Commissions shall comprise the Four Sectional Chairmen who shall be appointed by the Congress Organizing Committee. The Sectional Chairmen shall elect from among them their Commissioner. The Congress Organizing Committee may appoint local members as Sectional Vice-Chairmen.

Clause 7

The General Secretary-Treasurer shall convene a meeting, if required, of each Section, during Congress, to receive technical reports from Sections and/or Standing Committees.

Clause 8

Commissions and sectons may issue, at intervals, Newsletters and/or contribute to the Congress Organizing Committee Newsletter, specific progress reports for members.

Clause 9

Each Section may set up Standing Committees with a Convenor for each specific project. Any financial support for a Standing Committee shall require the approval of Council. Expenditure of approved funds shall be monitored by the Board of Trustees.

Clause 10

Each Commissioner shall report to each Congress and submit to the General Secretary-Treasurer copies of his records or findings for transmission to the Custodian.

Clause 11

Commissioners unable to attend Congress shall notify the General Secretary-Treasurer of his replacement who shall be one of the Sectional Chairmen within his Commission.

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ATRICLE X: *FINANCE*

Clause 1

The funds of the Society are:

(a) dues from corporate membership;

(b) the proceeds from the sale of Proceedings held by the Custodian;

(c) donations or bequests.

Clause 2

The Custodian shall close the accounts of the Society annually, have them

audited and returned to the General Secretary-Treasurer. A review of the Society's finance, accompanied by the Auditor's report, shall be submitted by the Custodian to the General Secretary-Treasurer for approval by Council.

Clause 3

The financing of the Congress shall be the responsibility of the Congress Organizing Committee. Income from dues received from affiliated, individual and institutional members shall accrue to the Congress Organizing Committee.

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ARTICLE XI : *GENERAL*

Clause 1

The Officers, members of Council, Commissions, Sections and Committees shall serve a term from the end of one Congress to the end of the following Congress.

Clause 2

No member other than Trustees, shall serve more than three terms in a particular office or position of the Society.

Clause 3

Amendments to the Constitutional Articles of the Society may be proposed to Council by 20 members or by unanimous decision of the Board of Trustees. Amendments shall require a two-thirds majority of Council and acceptance by a Plenary Session.

Clause 4

By-laws, consistent with the Constitution, to determine membership dues and to regulate the affairs of the Society, may be adopted by Council on the recommendation of the Resolutions Committee. These by-laws shall be recorded together with the Constitution in each edition of the Society's Proceedings.

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ARTICLE XII : *IMPLEMENTATION*

Clause 1

Immediately prior to the final Plenary Session of the XVIIth Congress the Administrative Committee shall be empowered to carry out the exceptional duties of the Council as provided for in the amended Constitution and adopted at a special Plenary Session of the XVIIth Congress. These exceptional duties shall be:

(a) to elect Trustees who shall, in the first instance, include *at least* five members of the Steering Committee appointed by Resolution No. 4 at the XVIth Congress;

(b) to determine dues for each class of membership;

ENERGY SYMPOSIUM

The Growing of Sugar Cane For Energy

by Dr. Roger P. Humbert

INTRODUCTION

In April, 1975 Dr. Melvin Calvin, Nobel-prize winning chemist from the University of California, Berkeley and the author were invited to Brazil (PLANALSUCAR) to discuss with their technologists the potential of growing sugarcane for energy on a large scale. A green light was given to their programs. President Geisel announced on Oct. 9, 1975 that a National Alcohol Comission would be created permitting the use of alcohol as a fuel, with up to 20% mixtures with gasoline, to reduce costly petroleum imports. Their National Alcohol Comission was established in November, 1975. By July, 1976 they had 14 new distilleries in operation. By August, 1977 they had 51 new distilleries producing at an annual rate of 3.65 billion liters. By September, 1978 they had 74 new distilleries producing at an annual rate of 4.5 billion liters. Brazil has not achieved these annual goals, as many distilleries have not produced continuously at their rated capacities for entire seasons, but their production is climbing dramatically.

The author is a consultant to many Usinas in Brazil, increasing sugarcane production per hectare and thus lowering the cost per liter of alcohol produced. Brazil averages 50 tons cane/ha., while the Usinas in the State of Sao Paulo average 65 tons cane/ha. Usina da Barra, for example now has 70% of their acreage averaging 90 tons cane/ha. They produce 3 million tons of cane per year, with one million tons cane processed directly into alcohol. All of the molasses produced from the two million tons cane for sugar is upgraded into alcohol. Usina da Barra is currently producing over 500,000 liters alcohol per day.

Doubling sugarcane production per hectare through improved cultural practices and varieties selected for their capabilities of "total sugars" production, rather than sucrose alone, result in approximately 30% reduction in costs per liter of alcohol produced. In this period of increasing costs of fossil fuels, sugarcane production for energy is certain to gain prominance in supplying a part of the energy needs of many developing countries of the Tropics that are now forced to import fossil fuels at ever-increasing prices.

Varieties Selected for Total Sugars Production:

Sugar cane varieties are being selected, not for their sucrose production, but for their "total sugars" production. Glucose and other reducing sugars are nearly

equal to sucrose in fermentation into alcohols. In fact, sucrose reverts to glucose prior to its conversion into alcohol, as shown in the following formula:

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \rightarrow 2\,\underset{\text{Glucose}}{C_6H_{12}O_6}$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{Alcohol}}{2C_2H_5OH} + \underset{\text{Carbon dioxide}}{2CO_2}$$

180 grams 92 grams

672 KCal 655 KCal

Varieties in order to be selected for alcohol production must have a high stalk population. High stooling varieties, such as NCo376 that have up to 160,000 stalks per hectare, are desirable. The variety must be fertilizer responsive and be able to use supplementary applications of fertilizer to continue its "boom stage" of growth until near harvest time. Variety L60-14 for example, in replicated variety trials at Hda. San Francisco, Tambo Valley, Peru produced 391 tons cane/ha. for alcohol in 26 months vs other varieties that produced as little as 128 TCH in the same period. Varieties are now available that can produce 200 TCH per year for alcohol!

The varieties selected for alcohol should be responsive to the chemical ripeners such as POLARIS and ETHREL, so that vegetative growth can be curtailed very quickly, and the sugars stored in the stalks-not used as energy for continued vegetative growth.

The varieties selected will have a full canopy of green leaves six weeks prior to harvest when the chemical ripeners are flown on. Desiccants such as Gramoxone (Paraquat) are then flown on ten days prior to harvest to improve the burns and reduce the trash-in-cane taken to the mill.

Supplementary Applications of Fertilizer:

Multiple supplementary applications of fertilizer, usually nitrogen (urea) and potash (muriate of potash) are applied at 5,7 and 9 months of age to keep the cane growing at optimum rates. With 14 or 15 green leaves in the canopy, less than 5% of the foot candle of energy falling on the upper leaves, ever reach the soil. With stalk populations up to 160,000 stalks/ha. there is no light at the base of the stools to encourage sucker growth unless lodging has occurred.

Application rates range from 50 to 100kg/ha. of urea and 50 to 100kg/ha. of muriate of potash per application. Heavy phosphate fertilization has been applied with the seed at planting time to encourage rapid root and shoot development. Total NPK application rates range from 200 to 300kg N/ha; F_2O_5 ranges from 100 to 200kg/ha; and K_2O ranges from 200 to 400kg/ha.

Continued feeding results in extended periods of "boom stage" of growth,

TABLE 1 Preharvest analyses of variety H37–1933 at lihue, hawaii

Field Yields	% 8–10 Stalk H_2O	% 8–10 Stalk N	% 8–10 Stalk K	% Reducing Sugars	% Sucrose	Tons Cane/ha.	Tons Cane/TS
17 TS/ha	80.7	0.42	0.68	11.8	37.5	178	10.62
17–25TSH	77.1	0.25	1.22	6.4	41.7	215	9.64
25–32TSH	75.3	0.19	1.47	5.7	46.2	197	7.13

in large diameter stalks with long internodes continuing until the chemical ripeners are applied. Balanced feeding is absolutely essential to keep the sugar cane plant growing at or near optimum rates. Table 1 shows data from Hawaii[5] stressing the fact that potassium deficiencies retard the conversion of reducing sugars into sucrose in the cane plant. These data show marked differences in sugar yields because of potassium deficiencies. The same cane produced for alcohol would show smaller differences, but still in favor of balanced nutrition for higher cane yields and higher total sugars production.

Optimum Moisture Conditions:

The supplementary fertilizer applications are timed when optimum moisture conditions exist. Supplementary irrigations are applied to prevent moisture from becoming a limiting factor of growth. At Usina Sao Luiz (Didini, Brazil) large block tests with multiple applications of fertilizer by airplane, with a new variety Co775 and supplementary sprinkler irrigation, increased cane yields from 80 tons cane/ha, to 177 tons cane/ha per year with significant reductions in costs per liter of alcohol produced.

The record yields of sugar cane production are now being produced where daily water balance charts are kept, considering the water storage capacities of the soils in the depth of rooting, pan evaporation from a free water surface, and water supplied either as rainfall or in irrigations. Tambankulu Estates in Swaziland, Africa grow up to 235 tons cane/ha. in 13 months of growth, which is 18 tons cane per hectare per month. During the "boom stage" of growth, after full canopy has developed, they apply 27mm of water every 3 days in solid set sprinkler irrigation. Their 1977 blocks treated with extra nitrogen and potash applications by airplane costing R157/ha. produced 27 tons cane/ha. extra, worth R280/ha. for a 78% profit.

Ripening Prior to Harvest:

In the growing of sugarcane for sugar, it has been necessary to preceed harvest with a ripening period of several weeks to several months in order to dehydrate the reducing sugars to recoverable sucrose. The formula is as follows:

$$2\ \underset{\text{Glucose}}{C_6H_{12}O_6} - H_2O \longrightarrow \underset{\text{Sucrose}}{C_{12}H_{22}O_{11}}$$

In the growing of sugarcane for alcohols and cellulose it is not necessary to ripen the cane and convert most of the sugars to sucrose. The reducing sugars are equally as important as sucrose in the fermentation processes.

Chemical ripeners and plant growth regulators are now being used commercially to convert the cane growing luxuriently to a cycle of sugar storage. In 1977, seventy-

five percent of the acreage of cane harvested in Hawaii used POLARIS to reduce the time required for ripening from as long as 7 months to 8 weeks, with approximately two tons sugar/ha. more "in the bag".

POLARIS is being used commercially in some 15 countries, with consistently good results, now that the varieties have been identified that respond to POLARIS. ETHREL is being used commercially in four countries on sugarcane, largely in Southern Africa. Other chemical ripeners have not given consistently good results in replicated trials with POLARIS and ETHREL in many countries.

Use of Vinaca for Soil Improvement:

The remainder of the fermented juice after alcohols have been distilled off, vinaca, is hauled or pumped back on the fields near the mill. Vinaca is acid and corrosive, so is usually hauled back to nearby fields in stainless steel tank trucks and trailers. Where irrigation is practiced, the vinaca is applied in the mill water to fields below the mill. If necessary , the vinaca and mill water are pumped to higher elevations to spread the large quantities of vinaca over larger areas so as not to build up excessively high levels of potash in the soils. Vinaca is usually applied at rates of 30 to 50m^3/ha. Vinaca is high in organic matter, and high in potash, particularly if molasses from sugar production is upgraded into alcohol along with juice from cane. Typical formulas of vinaca are shown in Table 2.

TABLE 2 Chemical composition of "vinaca" (Brazil)

	From Molasses	*From Cane Juice*
	%	%
Total Solids	6.4 –6.7	6.5 –6.7
Organic Matter	4.6 –5.0	4.8 –5.2
Mineral Matter	1.9 –2.1	1.4 –1.6
N	0.04–0.05	0.01–0.02
P	0.01–0.02	0.01–0.02
K	0.4 –0.7	0.1 –0.2
Ca	0.07–0.10	0.04–0.06
Mg	0.02–0.03	0.01–0.02
pH	4.2 –4.8	4.2 –4.6

In Hawaii, with continuous applications of irrigation water high in potassium, 1,000kg/ha. K_2O were applied per year, causing KCl to crystalize out in the cane juice. Application rates of 50m^3/ha. of vinaca means up to 350kg/ha. K_2O applied when the vinaca comes from molasses, per application.

As cane yields are increased, potassium removed from the soils will mean

higher potash fertilization requirements on 80 to 90% of the acreage in cane. Two million acres per year are now being planted to cane in Brazil for alcohol and cellulose production. A 100 ton crop of cane removes about 250kg K_2O, which must be replaced in fertilizers if continued high yields are expected. The 10 to 20% of the area that receives vinaca will receive no potash fertilizers. In the 80 to 90% of the acreage producing heavy cane tonnages (120-200 TC/ha./year) fertilizer formulas ranging from 2-1-2 to 2-1-4 are expected to be used in the future.

Energy Output/Energy Input for Sugarcane:

Sugar cane is the world's most efficient plant, on an annual basis, in the converting of sunlight energy into stored energy. Many plants actually have a negative energy balance of inputs to energy output. Detailed studies by the author have shown up to five times the energy stored as the total of energy inputs in seedbed preparation, fertilization, cultivation and herbicide usage, harvesting and cane transport. A part of the favorable energy balance is due to the long cycle of plant and many ratoon crops where high energy costs of planting occur only once in ten or more years. The ratoon crops have a much higher energy stored/energy inputs ratio than plant cane. They start faster, develop a full canopy of green leaves sooner. and store more total sugars per hectare per annum than plant cane.

Since energy is such an important factor in food, fiber and energy production, it is interesting to compare the energy expended to produce different crops. Table 3 compares the energy produced vs input energy for many crops.

TABLE 3 Energy content vs energy inputs for food crops

Food crop	Calorie Content per Calorie Input
Barley	6.6
Wheat	5.4
Sugarcane	5.0
Sweet sorghum Grain + stems	3.39
Stems only	2.27
Corn	3.3
Rice	2.6
Potatoes	2.1
Cassava	1.7
Apples	1.3
Dry beans	1.2
Grapes	1.1
Tomatoes	0.76
Peaches	0.73
Green beans	0.55
Oranges	0.43
Lettuce	0.34
Cauliflower	0.25

Even though barley and wheat have a higher energy output vs input ratio, the much higher total energy production per hectare per year for sugarcane, places this crop in a class by itself. The harvesting of sugarcane can be completely mechanized at a cost often lower than manual operations.

Value of Sugar Cane Bagasse Climbing:

Sugarcane bagasse, the fibrous material from which the juices and sugars have been extracted, is rapidly becomming as valuable as sugar or alcohol. Thirty-three countries now have cellulose plants using bagasse as the raw material, from which many pulp and paper products are produced. Cellulose from bagasse now has a value of US$270 per metric ton, and is climbing steadily. Brazil, for example, now imports 300,000 tons of pulp and paper products per year. By the mid 1980's they expect to export 2,000,000 tons of cellulose from sugarcane bagasse, eucalyptus and pine fibers to Europe and the United States. In processing sugarcane for alcohol, approximately 40% excess bagasse is not needed for power for processing the cane and for alcohol production, and can be used in cellulose plants.

Future for Alcohol Fuels from Sugar Cane Bright:

All sugarcane growing, petroleum importing countries in the Tropics have a potential of producing a part of their energy needs as alcohols from cane. Equipment costs are relatively cheap, when compared to the costs of sugar mills. Smaller sugar mills, no longer economic for sugar production, can be economic for alcohol production. 100,000 liters/day distilleries require only 60 tons cane per hour, or a relatively low milling capacity.

Since the juices are not converted into sugar, the power and energy requirements of the alcohol plants are far less than that for sugar mills. Consequently, capital investments are far less than those for sugar mills.

The costs of anhydrous alcohol production in a number of consulting mills of the author in Brazil average in a range of US$0.21 to $0.24 per liter. Average cane yields per hectare in Brazil are only 50 tons/ha., with the Sao Paulo mills averaging 65 tons cane/ha. As yields climb, first to 100 TCH and later to 150 and even 200 TCH, costs per liter of alcohol produced will decline. This will be in a period of ever-increasing costs of fossil fuels, so alcohol production for fuel from sugarcane has a bright future!!!

Economic Feasibility Studies:

Economic feasibility studies have been completed by your author for private sectors in Panama, South Africa, Costa Rica and the Philippines in the growing of sugarcane for energy——alcohol, cellulose and animal feeds. Contracts have already been signed for Brazilian distilleries in Costa Rica. Other contracts are certain to be

signed in the immediate future.

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	Members	Delegates
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2. Australia	114	56
3. Bangladesh	6	3
4. Barbados	6	2
5. Belgium	6	5
6. Belize	1	1
7. Benin	6	0
8. Bolivia	9	1
9. Brazil	170	48
10. Burundi	3	2
11. Canada	8	5
12. Colombia	34	12
13. Costa Rica	6	1
14. Cuba	20	20
15. Czechoslovakia	1	0
16. Denmark	3	2
17. Dominican Rep.	2	0
18. Ecuador	3	2
19. Egypt	24	6
20. El Salvador	3	1
21. Ethiopia	4	0
22. Fiji	10	6
23. Finland	2	2
24. France	27	13
25. Germany	28	17
26. Ghana	1	0
27. Guatemala	4	0
28. Guyana	9	3
29. Hongkong	1	0
30. India	104	39
31. Indonesia	75	29
32. Iraq	3	0
33. Italy	3	1
34. Ivory Coast	17	5
35. Jamaica	6	2
36. Japan	89	27
37. Kenya	25	19
38. Korea	2	1
39. Kuwait	1	1
40. Madagascar	1	1
41. Malawi	4	2
42. Malaysia	15	8
43. Mauritius	62	16
44. Mexico	56	16
45. Morocco	1	0
46. Mozambique	6	6
47. Netherlands	11	7
48. Nicaragua	1	1
49. Nigeria	5	1
50. Pakistan	28	8
51. Panama	1	0
52. Paraguay	1	1
53. Peru	17	6
54. Philippines	430	323
55. Puerto Rico	8	4
56. Reunion	36	13
57. Rhodesia	4	1
58. Singapore	4	4
59. Somalia	2	0
60. South Africa	77	46
61. Spain	4	2
62. Sri Lanka	1	0
63. Sudan	2	2
64. Swaziland	5	3
65. Sweden	6	4
66. Switzerland	6	3
67. Taiwan	20	7
68. Tanzania	4	1
69. Thailand	18	7
70. Trinidad & Tobago	19	3
71. Uganda	2	2
72. United Kingdom	75	35
73. Uruguay	1	0
74. U.S.A. (Mainland	129	57
incl. Hawaii)	38	17
75. Venezuela	35	7
76. Zambia	3	3
Total	1,988	953

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TECHNICAL PAPERS

CYCLIC CHANGEOVER FOR AGRONOMY FIELD TRIALS

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ABSTRACT

The use of cyclic change-over designs which provide an efficient method for determining residual effects of the treatment of one crop on the succeeding ratoon crop are discussed. The designs enable these effects to be measured with a minimum number of plots which is important in the management of experiments where time of harvest is a treatment.

INTRODUCTION

In the Queensland sugar industry, harvesting is carried out over a 20 to 26 week period between June and December. This period coincides with the optimum sugar (c.c.s.) levels in the cane which rise continuously from the start of the season to a plateau in the mid-September to mid-October period. The decline in c.c.s. after mid-October is accelerated by periods of heavy rain.

Weather conditions during the harvest season are normally fairly dry, although some storm activity bringing isolated rains can be expected from October onwards. The main season in Queensland normally occurs between January and March.

In a crop such as sugarcane which is grown on the basis of a plant crop and several ratoon crops cut annually, the time of cutting of one crop influences the growth of the following ratoons. This factor combined with the seasonal pattern of c.c.s. in Queensland, is an important consideration in determining optimum strategies for maximizing sugar yield over a crop cycle. In addition, the possibility of fertilizer applied to one crop, be it below or above optimum levels, influencing the yields of the next ratoon crop cannot be overlooked.

This paper describes trial designs which BSES has utilized in the study of residual effects of the management of one crop on the following ratoon crop.

MATERIALS AND METHOD

Initial studies (Anon[1,2,3] and Chapman and Leverington[4]) on crop cycles were carried out using a full factorial design, but because of practical difficulties

in burning and cultivating plots individually within the trial, the design was restricted to a three by three factorial with three times of harvest for the plant cane and three times of harvest for the first ratoons. Such a trial design provided information on the residual effect of the time of harvest for the plant crop, but was very specific in that it related to the particular climatic conditions of the year during which the test was conducted. Further information was gained by repeating the trial, but the design meant that the residual effect was measured in only one year out of the three during which the land was allocated to the experiment. In addition, three times of harvest gave little scope for determining whether residual effects and time of ratooning were related linearly or strongly curved towards the end of the season.

Balanced (BCO) and partially balanced (PBCO) changeover designs (Patterson and Lucas[7]) were examined and were considered to have potential for the study of crop cycle strategies. In these designs as few as ten plots were needed to examine residual and direct effects of five times of harvest. Trials could be conducted for two or more ratoon crops and residual effects calculated after a specified number of periods have been completed.

Attention was drawn to the work of Davis and Hall[5] who treated cyclic incomplete block (CIB) designs as changeover (CO) designs and developed a general method of analysis for a class of designs which they called changeover (CCO). In general these designs require even fewer units than those of Patterson and Lucas, but nevertheless possess average efficiencies for treatment, direct, and residual effects which compare very favorably. Some of the designs of Patterson and Lucas can be analyzed as changeover designs with increased efficiency.

Many different generating sequences for the cyclic designs are possible, and the efficiency increases with a greater number of periods in the design. The CCO design has the advantage that even though it may be designed for analysis after a large number, say four or five periods, analysis can be performed, although at lower levels of efficiency, from the second period onwards. In the processing of certain designs prematurely, singular matrices may be encountered during the statistical analyses, and consequently we have found it necessary to write a computer program which can predict when such problems will arise. In addition, this program defines the efficiencies of the various effects when analyzed at any particular harvest period. As with the designs of Patterson and Lucas, the CCO designs may be extended for an additional period beyond the normal design by repeating the treatment of the final period in the generating sequence. This has the effect of considerably increasing the efficiency of the determination of the overall treatment and direct effects. A typical example of the sequences and the efficiencies of a six-treatment design are set out below.

Cyclic changeover designs have now been used for crop cycling experiments with five and six times of harvest and ratooning and for nutritional trials with six levels of nitrogen application. Davis and Hall[5] published generating sequences for up to 20 treatments and five periods, and it would appear that these CCO designs are particularly suited to experiments where a large number of treatments are involved.

TABLE 1. Treatment sequences and efficiencies of the CCO design used in nitrogen trials at Mackay. (Treatments 6, periods 4, blocks 2) (Generating sequence 0132, 0314, Davis and Hall[6])

	Treatment Sequence											
	Block 1						Block 2					
Plot	A	B	C	D	E	F	G	H	I	J	K	L
Crop												
Plant	0	1	2	3	4	5	0	1	2	3	4	5
1R	1	2	3	4	5	0	3	4	5	0	1	2
2R	3	4	5	0	1	2	1	2	3	4	5	0
3R	2	3	4	5	0	1	4	5	0	1	2	3
4R *	2	3	4	5	0	1	4	5	0	1	2	3

	Efficiencies		
	Treatment (ignoring residual effects)	Direct effect	Residual effects
After 1R	singular	matrix	
" 2R	78	51	30
" 3R	90	81	57
" 4R *	86	85	73

**Recommended where practicable to improve residual effect estimates.*

RESULTS AND DISCUSSION

In an investigation by Leverington *et al.*[6] into the effects of time of ratooning on crop growth in the Burdekin area of Queensland, five times of harvest were scheduled as follows:

early June
end of July
mid-September
end of October
mid-December

The trial was designed for three periods and after planting in 1973 was harvested as plant, first, second, and third ratoon in 1974, 1975, 1976, and 1977 respectively. The third ratoon treatments were a repetition of those set out in the second ratoon. Two blocks of similar design were planted adjacent to the first experiment of 1975 and harvested as plant, first and second ratoon crops in 1976, 1977 and 1978 respectively. The two experiments have been analyzed as separate

trials and also as a combined experiment after deleting the third ratoon results. Four variety sub-plots were included in each treatment pilot of these trials.

Highly significant residual effects of time of ratooning on yield of cane and sugar in the succeeding ratoon crop were obtained in both trials. These effects are shown in Figure 1. Although the trends were similar in both sets of data the magnitude of the effect was somewhat greater in the first trial than in the second. The difference is probably related to the rainfall patterns in the December to February period during which the trials were conducted. These differences emphasize the need for spreading trials of such a nature over a number of years to obtain a better estimate of the effects under long-term average conditions. The results of the two trials are also consistent in that they both predicted very little growth on a mature crop during the July to October period. A similar type of trial in the hotter more humid area of Tully in North Queensland, has shown similar effects of time of harvest on the growth of the succeeding crop but has also indicated that crops in that area gain appreciably in weight during the normal period of harvest.

While these trial designs have provided useful information on the growth of cane during the harvesting season and the effect of time of ratooning, the analyses carried out do not specifically indicate whether an age of crop factor is involved in either cane or sugar production during the period of the year under study. This is one deficiency in the design if such information is important.

The four varieties in the trials were analyzed separately and again consistent results were obtained between the two experiments. While all varieties were adversely affected by ratooning in the latter part of the season, the effect on some varieties was more severe than on others.

The CCO design in Table I was applied to a series of three trials on different farms in the Mackay district to investigate residual effects of high rates of nitrogen application to cane crops. In these the treatments were raised from 0 to 300 kg N/ha in increments of 60 kg. In each trial two blocks of six treatments were required for the design and these were duplicated to give additional precision to the means. To check the prediction of the residual and direct effects obtained from the CCO design, three plots ("check plots") in each block were included. To these nitrogen was applied each year at 60/180, and 300 kg N/ha respectively.

Results of all three trials were consistent in that highly significant effects of the nitrogen applications were obtained. However there was no evidence of any residual effect. The direct effects predicted were virtually identical with those obtained form the corresponding "check plots" in the trial.

Although these results have given us great confidence in the CCO design it is difficult to envisage that there would not be some adverse residual effect on growth resulting from the absence of nitrogenous fertilizer from all crops in a cycle of plant and three ratoon crops. The form of analysis carried out provides only first order interactions i.e. it determines residual effects from only the immediately preceeding treatment and in these trials the effect of nitrogen

deficiency in one year did not affect stool vigour sufficiently to cause a measurable effect the following year. However the trials did not include a repeat of the final period treatment which would have greatly improved efficiency of the residual analysis. In future trials of this nature, this additional period will be included where it is practicable to take the trial to fourth ratoon.

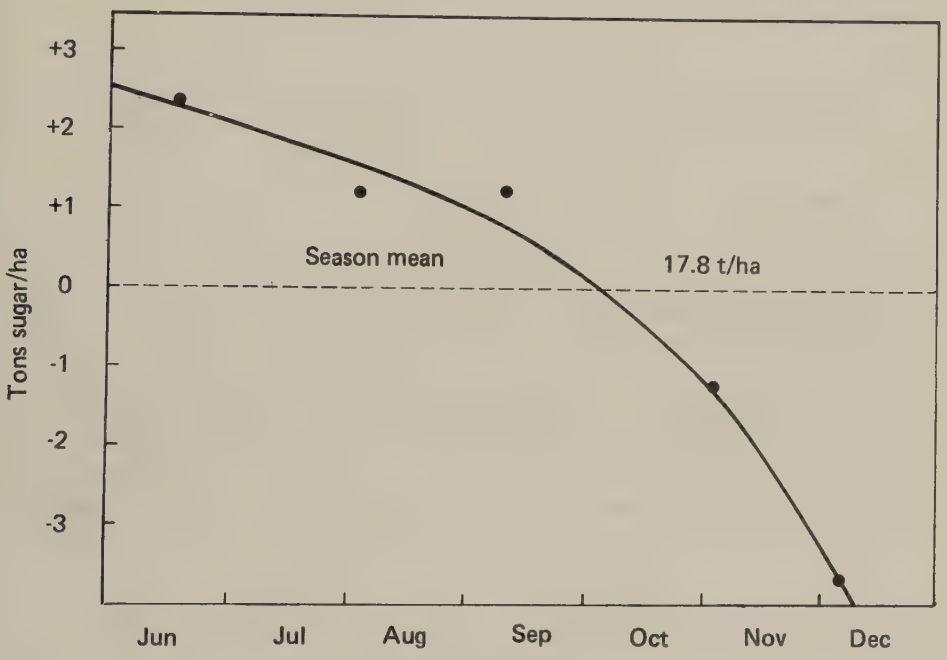

FIGURE 1. Residual effect of time of ratooning on yield of sugar (t/ha). Leverington and Hogarth "Cyclic" Change-over Designs for Agronomy Field Trials

CONCLUSION

Cyclic changeover designs provide a very useful tool for the sugarcane agronomist particularly when he is interested in trials which run for a number of ratoon crops. With a small number of plots the design enables a wide range of treatments to be studied in terms of both direct and residual effects.

To utilize the design efficiently it is desirable to examine a number of generating sequences to select ones which have the optimum levels of efficiency for the number of treatments required for the trial and for the periods when analyses are proposed to be carried out.

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DISEÑOS CICLICOS PARA ENSAYOS AGRONOMICOS DE CAMPO

K.C. Leverington y D. M. Hogarth

RESUMEN

Se discute el uso de diseños ciclicos que proveen un metodo eficiente para determinar efectos residuales del tratamiento de un cultivo en el subsiguiente cultivo de retoño. Los diseños permiten medir estos efectos con un minimo de parcelas lo que es importante en el manejo de experimentos donde la epoca de cosecha es un tratamiento.

THE INFLUENCE OF PLANT SEASON AND AGE AT HARVEST ON THE PRODUCTIVITY OF THE THREE SUGARCANE VARIETIES AT MUMIAS, KENYA

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Booker Agriculture International Ltd.,
London, England

ABSTRACT

Under the conditions at Mumias, Kenya, the amount and seasonal distribution of rainfall received by the crop is the main natural parameter affecting cane productivity, quality and consequently rate of sugar accumulation. The data presented in this paper indicate that the optimum age for harvesting the April plant crop is 84 weeks. Sugarcane planted in June should not be harvested before 84 weeks; however, thereafter sugar productivity is maintained until 100 weeks from planting.

October planted cane shows a steadily increasing rate in sugar production from 68 to 100 weeks. Considering the varieties separately, NCo 376 shows a peak in sugar productivity at 84 weeks. In comparison, the sugar production curves for Co 421 and Co 775 are very much less defined; consequently allowing greater flexibility in their harvest age. No optimum harvest age is indicated by the first ratoon results, thus affording valuable flexibility in the management of ratoon crop harvests. There is a seasonal preference for the planting of the three varieties, with NCo 376 leading Co 421 and Co 775 in the April and June plantings, while Co 421 has the highest cane productivity following October planting. While Co 421 produces more cane than the other two varieties in the first ratoon, its low juice quality results in there being no significant differences between varieties in sugar production. The practical applications of the results are considered.

INTRODUCTION

The work reported in this paper was initiated in 1975 when NCo 376 and Co 775 were recommended as meriting commercial propagation in addition to the variety Co 421. During the conduct of the feasibility studies, highly significant linear

yield increases with age were found in Co 421, as well as some indications that the planting season might be important. Subsequent trial results with NCo 376 and Co 775 had indicated that they were early maturing. It was, therefore, decided to determine the effect of time of planting on cane yield, and the maturation of these main varieties with a view to ascertain their optimum ages for harvest in order to maximize economic sugar production.

The data were collected by the Agronomy Section of the Mumias Sugar Company, whose estate is situated in the north-western part of Kenya at about 1,300 m above sea leavel. The mean annual rainfall over the past 11 years has been 2,000 mm. There is generally a long rainy season period from March to June, and a second rainy season in October. The intervening months are slightly drier – especially July; but the real dry season starts in November lasting through February. Mumias enjoys relatively uniform temperatures throughout the year, with the mean maximum monthly temperatures ranging from 27.6°C in July to 31.3°C in January. The mean minimum temperatures range from 13.3°C to 15.2°C. Daily evaporation varies slightly throughout the year, with the mean monthly values reaching the lowest values in July (3.8 mm/day) and the highest values in February and March (5.7 mm/day). The mean relative humidities have varied between 58.5% and 73%.

EXPERIMENTAL PROCEDURE

This experiment was conducted in upland soil in a randomized split-plot design with two replications. Three whole plots for each season were planted in June and October 1975, and April 1976, with the varieties under test – Co 421, Co 775 and NCo 376. Each varietal plot was divided into five randomly allocated sub-plots of ages at harvest. The gross sub-plots were four rows of 10 m at 1.67 m spacing, and the net sub-plots were two rows of 7 m.

Fertilizer was applied at the following rates to ensure optimum nutrition:

Crop	Timing	N	Carrier	P_2O_5	Carrier
Plant	At planting	52 kg/ha	CAN	105 kg/ha	SSP
	At 5-6 months	39 kg/ha	CAN	–	
First ratoon	Following plant crop harvest	52 kg/ha	ASN	50 kg/ha	SSP
	At 5-6 months	39 kg/ha	ASN	–	

As soil analyses showed adequate K concentration (0.4 me), no potash fertilizer was required.

The sub-plots were harvested at two monthly intervals from 16 to 24 months of age in the plant crop, and 15 to 23 months of age in the first ratoon crop. The net plot cane yields were recorded at harvest; and the pol percent juice together with the other components of juice quality were determined on samples of 12 randomly selected stalks from each net plot. These data were used to derive

TABLE 1. Harvest Data of Sugarcane Plant Crop as affected by variety, season and ages at harvest

		Harvest data Plant Crop TC/ha/week	TERS/ha/week	Brix%	ERS%C	Juice purity	Fiber % Canes
Varieties	NCo 376 (A_o)	2.12 a	0.26 a	20.4 a	12.30 a	89.8	11.5
	Co 775 (A_1)	1.86 b	0.22 b	20.1 a	12.00 a	90.0	12.2
	Co 421 (A_2)	2.03 ab	0.22 b	18.7 b	10.56 b	87.6	12.3
Standard deviation		± 0.13	± 0.02	± 0.9	b 0.93	± 1.3	± 0.4
Coefficient of variation %		6.50	8.70	4.6	8.00	1.5	3.3
Seasons	June (B_o)	1.72 b	0.19 b	19.4	10.72 b	87.1 b	12.8 n
	October (B_1)	2.12 a	0.26 a	20.0	12.12 a	89.8 a	11.5 a
	April (B_2)	2.18 a	0.26 a	19.8	12.02 a	90.5 a	11.7 ab
Standard deviation		± 0.25	± 0.04	± 0.3	± 0.78	± 1.7	± 0.7
Coefficient of variations%		12.45	16.67	1.5	6.71	1.9	5.8
Ages at harvest	67.8 weeks (C_o)	2.06 ab	0.22 b	18.3 c	10.31 b	85.7 c	11.4 b
	75.8 weeks (C_1)	2.18 a	0.25 a	19.5 b	11.16 b	88.0 bc	12.3 ab
	83.8 weeks (C_2)	2.02 abc	0.25 a	20.1 ab	12.36 a	91.0 a	11.4 b
	91.8 weeks (C_3)	1.93 bc	0.23 ab	20.2 a	12.02 a	89.9 ab	12.2 ab
	99.8 weeks (C_4)	1.84 c	0.22 b	20.5 a	12.27 a	91.0 a	12.8 a
Standard deviation		± 0.13	± 0.02	± 0.9	± 0.87	± 2.3	± 0.6
Coefficient of variation%		6.50	8.70	4.6	7.49	2.6	15.0

Note: Duncan's Multiple Range Test @ $P < 0.05$

estimated recoverable sugar percent cane (ers%c), and tons estimated sugar per hectare (ters/ha).

Unfortunately, no first ratoon results were available for the cane initially planted in April because of mill closure prior to this treatment's scheduled harvest.

RESULTS

Plant Crop

Variety and Variety x Season of planting interaction

Averaged over season and ages at harvest, cane productivity of NCo 376 was slightly but not significantly higher than that of Co 421, and is significantly better than that of Co 775. The differences are more marked in sugar production, as Co 421 has a significantly lower quality. Consequently, the rate of sugar production of NCo 376 is 18% higher than Co 775 and Co 421 (Table 1).

The varietal x planting season interaction showed that the superiority of NCo 376 in cane productivity was not invariable. NCo 376 was distinctly superior in the June planting, superior in the April planting, but slightly inferior to Co 421 in the October planting. This interaction, data for which are shown in Table 2, is highly significant ($P < 0.01$).

TABLE 2. Season of planting x varieties — cane productivity (tc/ha/week) across ages of cane at harvest

	Seasons of planting			
Variety	April	June	October	Mean
NCo 376	2.40	1.87	2.11	2.13
Co 775	1.89	1.61	2.09	1.86
Co 421	2.25	1.68	2.17	2.03
Mean	2.18	1.72	2.12	

Season of planting

June planting results in significantly lower productivities of both cane and sugar, and in lower quality (Table 1). Some caution is necessary however, in interpreting the magnitude of these effects as the coefficient of variation are high.

Age at harvest

The cane was harvested at five ages in increments of eight weeks, from

67.8 to 99.8 weeks of age. Regression analysis indicated a definite negative linear relationship between tc/ha/week and age ($P < 0.001$). However, the age x planting season interaction was equally significant, so that the three planting dates must be considered separately.

In the June-planted cane (i.e., the season of lowest productivity), cane yield/week increased with age of harvest ($r = +0.849$, $P < 0.05$). In the April-planted cane the reverse was true ($r = -0.926$, $P < 0.01$), the rate of decline in this season was double the rate of increase in the June-planted cane (0.019 compared to 0.008 tc/ha/week per week delay in harvest). No significant relationship could be found for the October planting. These data are illustrated in Fig. 1.

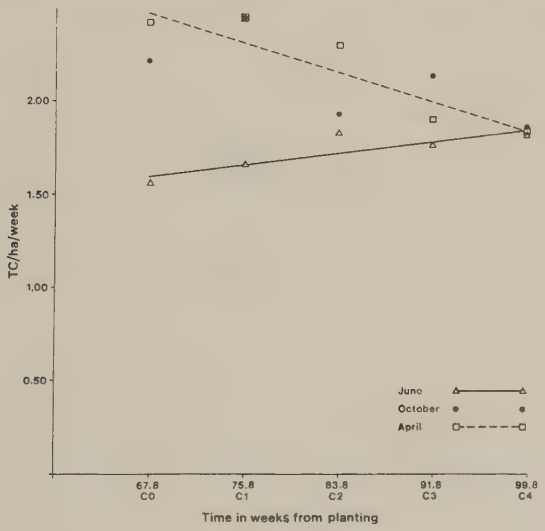

FIGURE 1. TC/ha/week Season of planting x Ages at harvest

In contrast, cane quality improved with age, at least up to 84 weeks of age. Average for all seasons of planting, both the linear and the quadratic components of the regression between age and ers%c were significant (both with $P < 0.001$). Similarly, the regression between age and ters/ha/week showed significant linear ($P < 0.001$) and quadratic ($P < 0.05$) components.

Again, responses differed with season of planting. In the April planting, the relationship was definitely quadratic, with both linear and quadratic components being significant. For the June planting only the linear component achieved significance ($r = +0.90$, $P < 0.01$), but the data shown in Fig. 2 illustrate that cane quality appears to peak at about 84 weeks for both planting seasons.

No relation was found between age and quality in the October planting.

Conversion of the cane and quality data into ters/ha/week is given in Fig. 3

for season of planting and in Fig. 4 for variety.

Clearly, the efficiency of sugar production peaks at about 84 weeks in the April-planted cane; while in June-planted cane the rate of sugar productivity is maintained from 84 to 100 weeks, albeit at a lower level (Fig. 3).

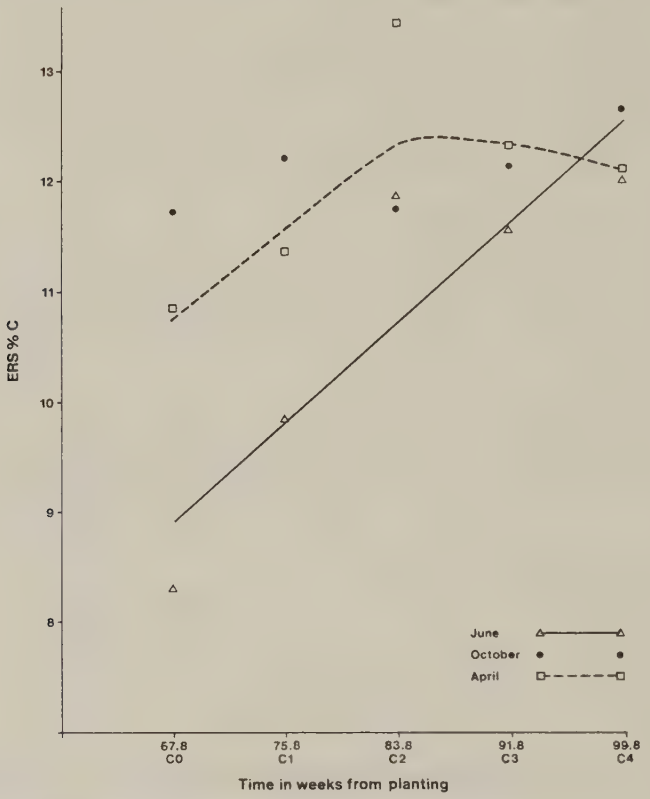

FIGURE 2. ERS%C Season of planting x Ages at harvest

The October planting appears to increase production efficiency with age ($r = +0.894$, $P < 0.01$), but the slope of the line is very small, the rate of productivity improving by only 0.04 ters/ha over the 32-week period.

All three varieties show a peak of efficiency in production at about 84 weeks. This is most marked in NCo 376 which at this age, outyields the other varieties by about 0.03 ters/ha/week, or 14% (Fig. 4).

First Ratoon Crop

Variety and Variety x Season of planting interaction

The average for all seasons of planting and ages at harvest, the cane pro-

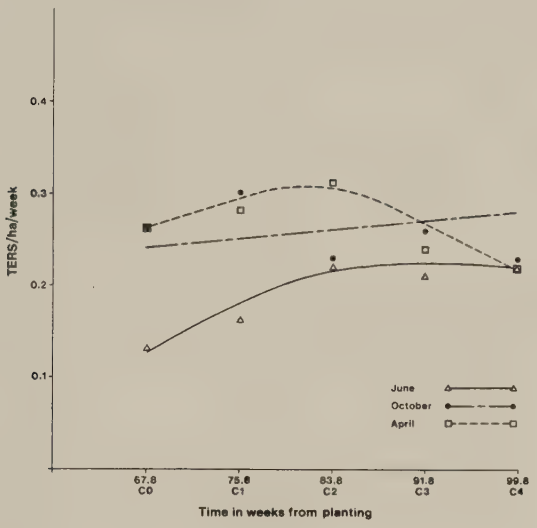

FIGURE 3. TERS/ha/weeks Season of planting x Ages at harvest

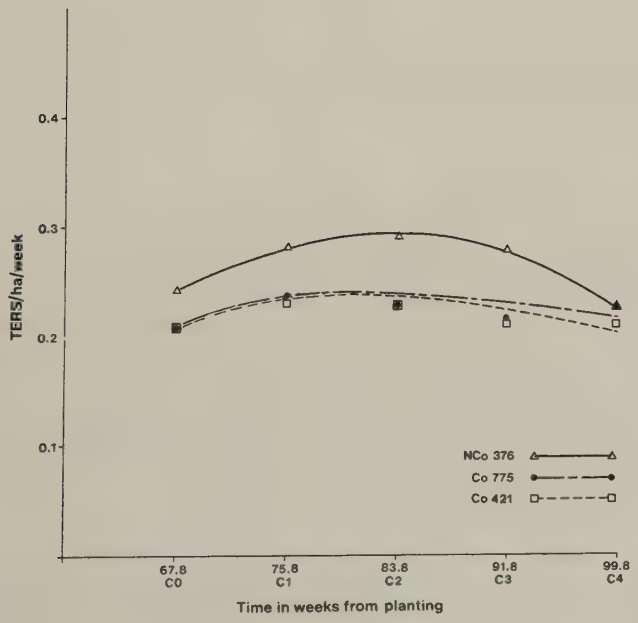

FIGURE 4. TERS/ha/week Varieties x Ages at harvest

ductivity of Co 421 was higher than that of NCo 376 (albeit not significantly so), and significantly higher than that of Co 775. However, because cane quality was lowest in Co 421, there were no significant differences in sugar production between the varieties (Table 3).

In contrast to the plant crop, there were no significant interactions between varieties and seasons of planting in the first ratoon crop. However, there was an overall increase in the rate of cane production from plant to first ratoon (Tables 2 and 4).

TABLE 4. Season of planting x varieties – cane productivity (tc/ha/week) across ages of cane at harvest

	Seasons of planting		
Variety	June	October	Mean
NCo 376	2.29	1.97	2.13
Co 775	2.11	1.97	2.04
Co 421	2.43	2.21	2.32
Mean	2.28	2.05	

Season of planting

June-planted cane had higher rates of cane productivity, of lower quality than that planted in October, however, none of the differences recorded in Table 3 were significant.

Age at harvest

Since the plant crop had been harvested at five ages in increments of eight weeks, first ratoon crop was also of different ages when each season's treatments were harvested all at once. The order of maturity was, however, reversed so that the oldest plant harvest age treatment became the youngest first ratoon treatment.

Considering the two ratooning dates separately, negative linear regressions where shown for cane productivity (Fig. 5). In the June-planted cane production declined with age at harvest at a rate of 0.13 tc/ha over 32 weeks ($r = -0.976$, $P < 0.001$), while October-planted cane depreciated at more than twice this rate over the same period @ 0.29 tc/ha ($r = -0.929$, $P < 0.01$).

In contrast, cane quality improved with age (see Table 3). Average over both seasons of planting, the linear component of the regression between age and ers%c was highly significant ($P < 0.001$). Considering the two ratooning dates separately, the linear component achieved significance for both (June @ $r = +0.943$, $P < 0.01$ and October @ $r = 0.964$, $P < 0.001$). Figure 6 illustrates these data.

TABLE 3. Harvest Date of Sugar Cane Ratoon Crop as affected by varieties, seasons and ages at harvest.

		Harvest data	First ratoon crop				
		TC/ha/week	TERS/ha/week	Brix%	ERS%C	Juice purity	Fiber % cane
Varieties	NCo 376 (A_o)	2.13 ab	0.25	21.0 a	11,68 a	90,3 a	14.5
	Co 775 (A_1)	2.04 b	0.23	20.9 a	11,47 ab	90,7 a	15,5
	Co 421 (A_2)	2.32 a	0.24	19,6 b	10,44 b	88.2 b	14,7
Standard deviation		± 0.28	± 0.01	± 0.8	± 0,66	± 1,3	± 0.5
Coefficient of variation %		6,47	4.17	3.9	5,89	1.4	3,4
Seasons	June (B_o)	2.28	0.25	20.2	11,10	89,7	14,7
	October (B_1)	2.05	0.23	20.8	11.29	89,7	15,1
Standard deviation		± 0.16	± 0.01	± 0.4	± 0,13		± 0,3
Coefficient variation %		7.37	4.17	2.0	1,16		2,0
Ages at harvest	93.1 weeks (C_o)	2.03	0,24	21.4 a	11,99 a	91,5 a	15,2
	85.1 weeks (C_1)	2.20	0.25	21.0 ab	11,57 ab	90,9 ab	15,5
	77.1 weeks (C_2)	2.12	0.23	20.5 bc	10,87 b	89,2 bc	15,6
	69.1 weeks (C_3)	2,16	0.23	19,9 cd	10,79 b	88,8 cd	14,5
	61.1 weeks (C_4)	2,31	0.25	19,6 d	10,75 b	88,2 d	13,7
Standard deviation		± 0,10	± 0.01	± 0.7	± 0,56	± 1,4	± 0,8
Coefficient of variation%		4.63	4.17	3.4	5,00	1,6	5,4

Note: Duncan's Multiple Range Test @ <0.05

There was no significant decline in the rate of sugar production (ters/ha/week) with age at harvest across ratooning dates (Table 3); nor was there when the ratooning dates were considered (Fig. 7).

To facilitate the interpretation of the results, the planting and harvesting dates of the plant and first ratoon crops are shown in Figure 8, together with monthly rainfall and temperature data.

Plant crop

Of the three varieties, NCo 376 had the highest rates of cane and sugar production when expressed at t/ha/week, (Table 1 and Fig. 4). Unfortunately, no definite conclusions can be drawn on the cane production, ers%c and conseuquently sugar productivity in relation to season of planting because of high coefficients of variation. Nevertheless, the relatively lower temperatures and rainfall during the June-planting resulted in the lowest productivity of the seasonal plantings (Fig. 8 and Table 1).

The data in Table 2 indicate a significant varietal x season of planting inter-

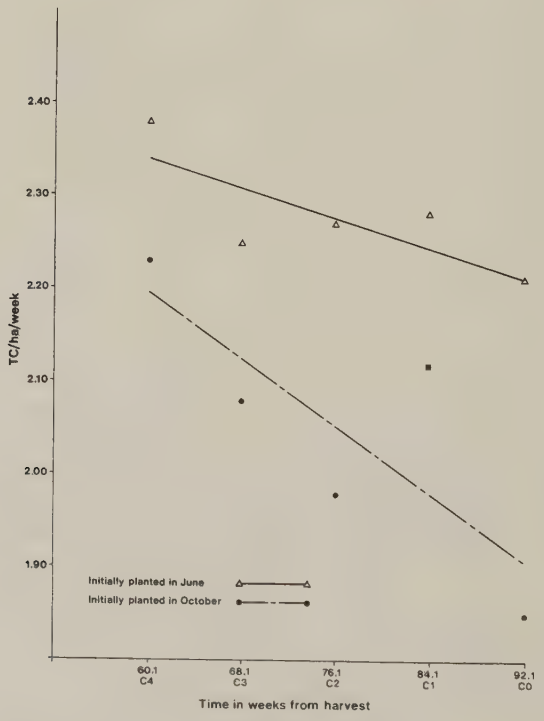

FIGURE 5. TC/ha/week—First ratoon
Ratooning dates x Ages at harvest

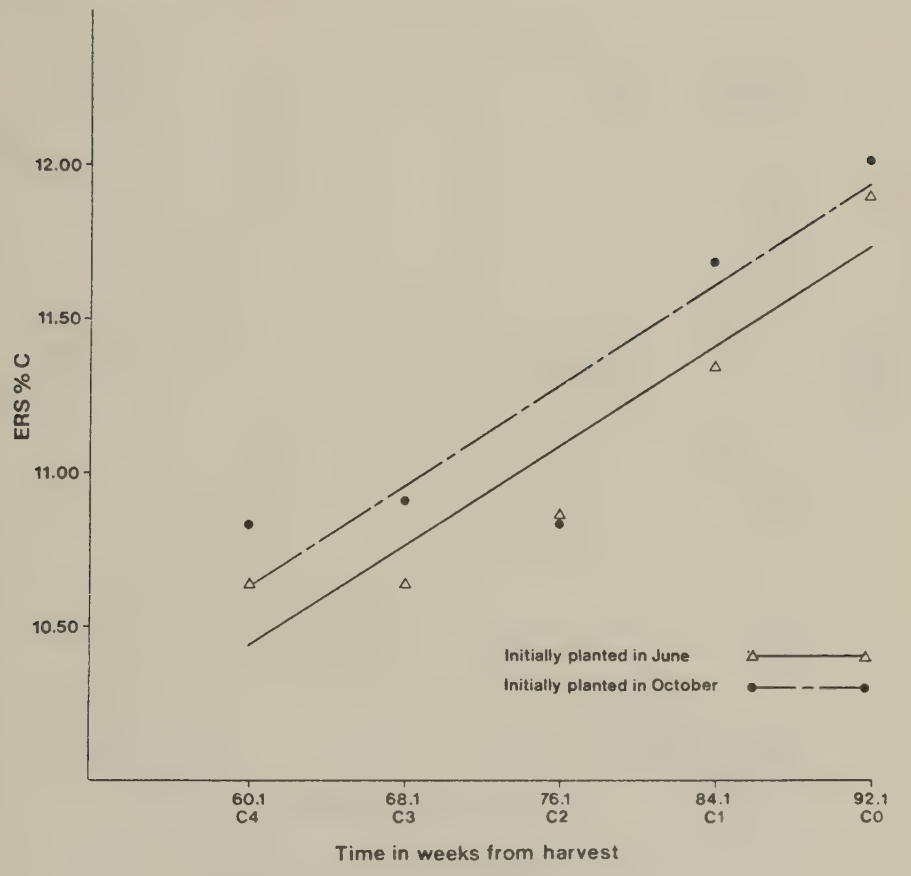

FIGURE 6. ERS%C – First ratoon
Ratooning dates x Ages at harvest

action. In comparison with the other two varieties, NCo 376 had the highest cane production when planted in April and June, while Co 421 produced its highest rates of cane production following October planting. The results in Table 2 consequently indicate a seasonal preference for the planting of the three varieties namely:

Season of planting	*Order of preference*
April	NCo 376; Co 421; Co 775
June	NCo 376; with little difference between Co 421 and Co 775
October	Co 421; with little difference between NCo 376 and Co 775

Gosnell has reported that increasing age reduced crop growth rate and consequently yield increment to a very marked degree in irrigated sugarcane. Similarly, under rainfed conditions in this experiment, Figure 1 shows that the cane pro-

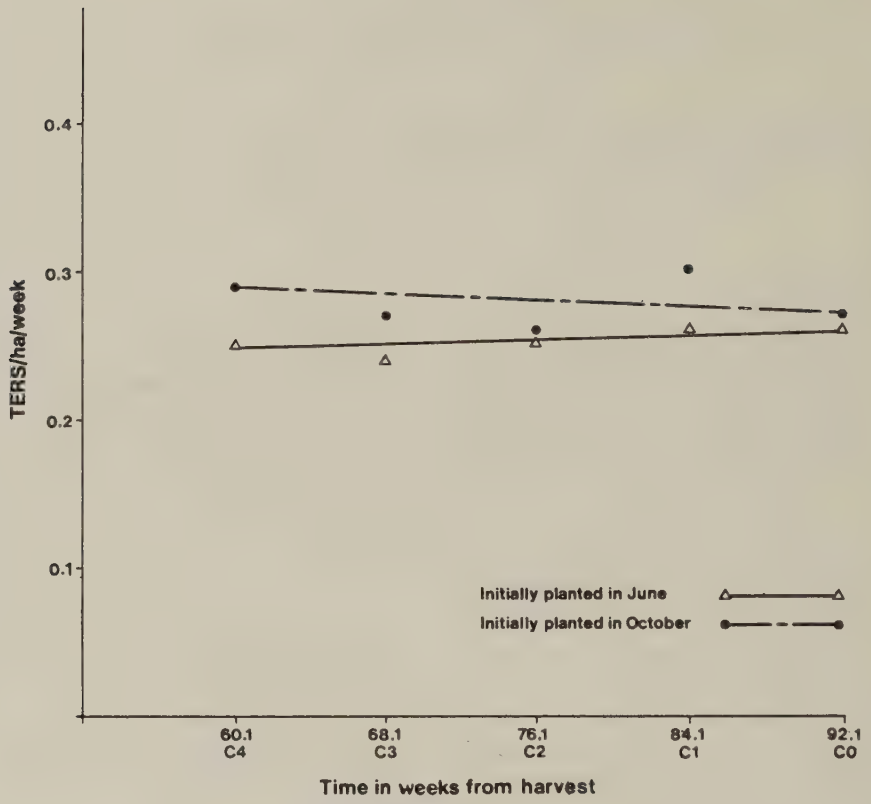

FIGURE 7. TERS/ha/week – First ratoon
Ratooning dates x Ages at harvest

duction of April-planted cane declined in relation to increasing age at harvest. Conversely, ers%c increased to a peak of approximately 12.4 at 84 weeks from planting thereafter declining (see Figure 2). Consequently, sugar productivity also reached a maximum 84 weeks after planting (See Figure 3).

The decline in April-planted cane production is correlated with the rainfall received by the crop two months prior to and during the five sequential harvests (Fig. 8). In contrast, the June-planted cane productiion increased in relation to age at harvest, albeit at a low rate (Fig. 1), while the rate of ers%c increase in relation to age at harvest was much greater (Fig. 2). Though the cane production and ers%c data have significant correlation coefficients ($r = +0.849$ @ $P < 0.05$ and $r = +0.900$ @ $P < 0.001$, respectively, their relationships with time indicate curvi-linearity (Fig. 1 and 2) – the point of flexure being at approximately 84 weeks after planting. The fact that sugar productivity would also appear to reach a plateau 84 weeks after planting in June-planted cane supports this observation (Fig. 3).

The rainfall recorded during March through June 1977 influenced the cane

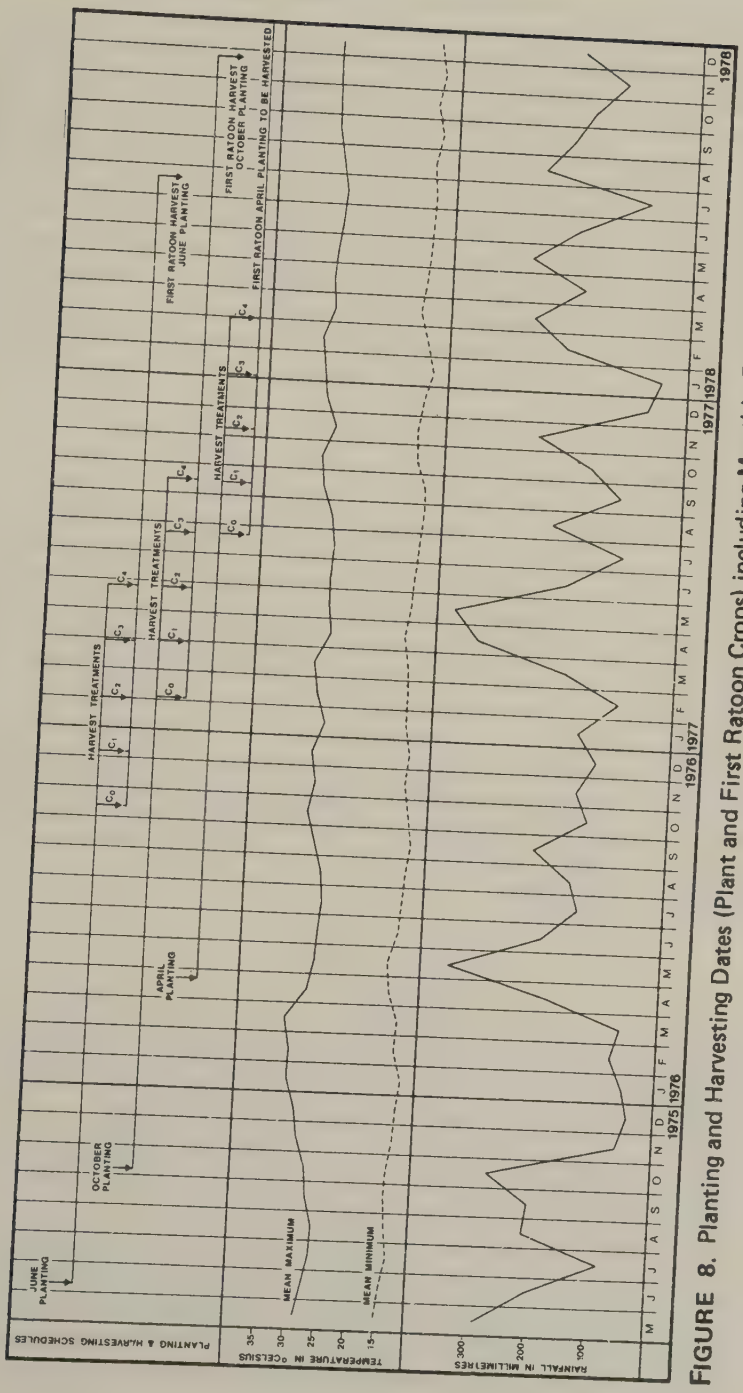
PLANTING & HARVESTING SCHEDULES
JUNE PLANTING
OCTOBER PLANTING
APRIL PLANTING
HARVEST TREATMENTS
C_0
C_1
C_2
C_3
C_4
FIRST RATOON HARVEST JUNE PLANTING
FIRST RATOON HARVEST OCTOBER PLANTING
FIRST RATOON APRIL PLANTING TO BE HARVESTED
TEMPERATURE IN °CELSIUS
MEAN MAXIMUM
MEAN MINIMUM
RAINFALL IN MILLIMETRES
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1975 1976 1977 1978

FIGURE 8. Planting and Harvesting Dates (Plant and First Ratoon Crops) including Monthly Rainfall and Temperature Data

production and ers%c data for the 1975 October planted cane (Fig. 8); consequently no significant relationship was demonstrated for these two parameters with respect to age at harvest (Fig. 1 and 2). There was a significant correlation coefficient for the ters/ha/week data ($r = +0.894$ @ $P < 0.01$). These data are illustrated in Fig. 3. Consequently, the data indicate that the age plant cane should be harvested as affected by the season of planting. While the rate of sugar production increased steadily over the 32 weeks of the trial in October-planted cane; in June-planted cane, maximum sugar productivity was reached at 84 weeks after planting, and was maintained at this rate thereafter. In contrast, there was an optimum time (84 weeks) for the harvest of April-planted cane. Irrespective of the season of planting, Fig. 4 shows that the peak in sugar production for NCo 376 occurs approximately 84 weeks after planting. In contrast, the sugar productivity curves are much flatter for Co 421 and Co 775, indicating that the plant crop harvest of both varieties can be delayed beyond 84 weeks without incurring appreciable losses in sugar yield.

First ratoon yield

The cane yield advantage shown by Co 421 over the other two varieties was offset by its low quality. Consequently, there were no significant differences between rates of sugar production between varieties. The cane and sugar productivity differences between the crops initially planted in June and October were influenced by the amounts of rain received by each crop just prior to its harvest (Fig. 8). The rainfall over the March through May period 1978 while producing higher first ratoon cane yields in the June-planted cane depressed its quality compared wth the October-planted cane. Conversely, the comparatively lower rainfall over the July through September period 1978 improved the quality of the October-planted cane but suppressed its productivity in the first ratoon. Fig. 5 and 6 show that while the rate of cane production decline with age ers%c improved. Consequently, there was no difference in the rate of sugar accumulation between cane harvested at 60 weeks and that harvested at 92 weeks.

CONCLUSIONS

As there are no wide fluctuations in either maximum or minimum temperatures, the amount and seasonal distribution of rainfall received by the crop is the main natural parameter affecting cane productivity, quality and consequently the rate of sugar accumulation under Mumias conditions (Fig. 8).

The results, so far, indicate that the largest proportion of planting should take place in April with the balance in October.

The data also show that the optimum age for harvesting the April plant crop is 84 weeks. Sugarcane planted in June should not be harvested before 84 weeks; however, thereafter, sugar productivity is maintained until 100 weeks after planting. October-planted cane shows a steadily increasing rate in sugar production from 68 to 100 weeks. Considering the varieties separately, NCo 376 showed a peak in sugar productivity at 84 weeks.

In comparison, the sugar production curves for Co 421 and Co 775 are flatter; consequently allowing greater flexibility in their harvest age. As no optimum harvest age is indicated by the first ratoon results, additional valuable flexibility is allowed in the management of ratoon crop harvests under the conditions obtaining at Mumias, increasing the harvest age of any crop class consequently decreases the cost of sugar production from it. In seasons of good growth following wet seasons when the subsequent cane yields will be high. No appreciable losses in sugar yield should be recorded if the cane is harvested at two years old. In contrast the data indicate that ratoon crop harvests could be brought forward to 60 weeks from cutting the previous crop following a drought or a season of sub-normal rains when subsequent growth would have been poor. In such a situation the early harvest of the ratoons will enable the following ratoon to profit from subsequent rains.

To further evaluate this trial, so that more comprehensive recommendations can be made, the harvest results of a complete cycle (plant plus three ratoons — the current estate of practice) should be studied.

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LA INFLUENCIA DE LA TEMPORADA Y EDAD DE COSECHA, EN LA PRODUCTIVIDAD DE LAS TRES VARIEDADES DE CAÑA DE AZUCAR EN MUMIAS, KENYA

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RESUMEN

Bajo las condiciones prevalesciente en Mumias, la cantidad y distribucion estacional de la lluvia recibida por la cosecha es el principal parametro natural que afecta la produccion cañera, calidad y consecuentemente el contenido de azucar acumulado. Los datos presentados en este trabajo indican que la edad optima para cortas de la cosecha sembrada en Abril, es a las 84 semanas. La caña de azucar sembrada en Junio no debe ser consechada antes de las 84 semanas; sin embargo, a partir de entonces la produccion de azucar es mantenida hasta 100 semanas luego de sembrada. La caña sembrada en Octubre presenta un continuo aumento en la produccion de azucar de las 68 a 100 semanas. Considerando las variadades separadamente, NCo 376 demuestra una produccion maxima en productividad de azucar a las 84 semanas. En com-

paracion, las curvas de produccion de azucar para Co 421 y Co 775 son menos definidas, por consiguiente permitiendo una mayor flexibilidad en su edad de cosecha. La edad optima de cosecha no es indicada por los resultados en retoño, por lo cual proporciona una apreciable flexibilidad en el manejo de la cosecha del retoño. Hay una preferencia estacional para la siembra de las tres variedades, con NCo 376 preferentemente sobre Co 421 y Co 775 en la siembra de Abril y Junio, mientras la Co 421 tiena la mayor productividad de caña en primer retoño que las otras dos variedades, la baja calidad da su jugo de lugar a que no haya diferencia significativa en la produccion de azucar entre las variedades. La aplicacion practica de los resultados son considerados.

INTERCROPPING OF FIRST RATOON SUGARCANE WITH RICE IN MAURITIUS

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ABSTRACT

A study was undertaken to investigate the possibility of intercropping ratoon sugarcane with rice. When intercropped as upland rice in inter-rows of sugarcane planted at the conventional row spacing of 1.50 m, rice varieties used in flooded paddies of Mauritius showed very low yields. Intercropped rice had no significant adverse effects on the sugar yields. Yields up to 1.6 tons/ha were obtained with short-cycle rice varieties planted in every second inter-row (227 cm) of 1st ratoon sugarcane in 'pineapple' planting arrangement (227 cm and 97 cm) under irrigated conditions. Up to 0.9 tons of rice per ha were obtained under rainfed conditions.

INTRODUCTION

Intercropping of May-June planted sugarcane has been well-adopted by small and big planters in Mauritius. Among the crops, beans, peas, and potatoes have been recommended for intercropping on the basis of soil suitability and availability of irrigation facilities. As a result however, of the increasing demand for other food crops and the limited cultivated land, the need to exploit the cultivable inter-rows of ratoon sugarcane arose. Thus, groundnut, maize, and soybean are now being planted in inter-rows of the first and second ratoons. Recently, it had become necessary to study the possibility of intercropping sugarcane with rice.

Mauritius consumes some 60,000 tons of processed rice annually, representing an expenditure of Rs 100 m. It is therefore important to increase rice production, which now is a mere 400 tons annually from flooded paddy fields. Because of the uneven topography of the island and the rocky nature of the soils, conventional rice cultivation by flooding would demand very excessive investments and high water consumption. It appears that rainfed or overhead irrigated upland rice cultivation may offer more attractive prospects on any attempt to increase rice production on a large scale.

This paper deals with a study of intercropping sugarcane ratoons with upland rice under irrigated and rainfed conditions. The effect of competition

between rice and the main crop was determined when rice was intercropped in sugarcane planted at the conventional spacing of 1.5 m between rows. On account of shortage and high cost of labor, mechanization of harvesting and planting of cane has recently been tried in Mauritius. This resulted in changes particularly in the traditional row spacing. Such changes which included planting sugarcane alternately in rows 227 cm and 97 cm apart, were found to have no adverse effect on cane and sugar yields. The wider rows, at the same time, provided an attractive possibility for intercropping rice. Competition between the two crops is less when the wider rows are used.

MATERIALS AND METHODS

Experiment I

In the first experiment, a randomized block design with 6 replicates was used, with three rice varieties, direct-seeded as intercrops in first ratoons of sugarcane S 17 at Fuel , and M 438/59 at Belle Vue Haral. Two additional treatments, cane grown alone and transplanted TN1 rice seedlings as intercrop, were also included. The empirical plot consisted of 4 rows of sugarcane 8 m long and spaced at 1.50 m. Four rows of rice were planted in every second cane inter-row. Inter-row spacing of the intercropped rice was 20 cm. Plots were irrigated at a rate of 18 mm every 3 days. The plots were harvested when the various rice varieties reached maturity and when the sugar cane reached the 12th month. Data on rice grain and sugar yields at FUEL were subjected to an analysis of variance. Significance of analysis results was based on the 5% level of probability.

Experiment II

Three rice varieties in the second experiment were intercropped in first ratoon crop of sugarcane under irrigated and rainfed conditions. The trials were conducted in two sites on two dates under the conditions listed in Table 1.

RESULTS AND DISCUSSION

In Mauritius, the sugarcane crop is usually grown at a spacing of 1.5 m between the rows. The cane is grown in furrows and the leaves of the cane do not shade the inter-rows until 4 to 5 months after planting. With the first ratoons, under conditions of high temperatures and adequate moisture, as were the case in the present experiment, shading of inter-rows occurred earlier, that is, 3½ to 4 months after cropping. Yields of rice variety TN1 (the commercially grown rice variety) at Fuel (Table 2) was very low. A very high percentage of the seeds were due to the shading of cane interrows during grain filling period of rice (Fig. 1). The more rapid and vigorous growth of the cane variety M 438/59 at Belle Vue Harel, severely affected grain filling of the rice varieties. The results showed that the rice varieties had too long a growth cycle and were not suitable as intercrops. However, it was found that

the rice varieteis planted in every second cane inter-row, had no significant adverse effects on sugarcane and sugar yields, as shown in Table 3.

TABLE 1. Experimental conditions at Fuel and Benares

Condition	Fuel	Benares
Altitude	125 m	100 m
Soil type	Low Humic Latosol	Low Humic Latosol
Soil pH	5.35	5.7
Cane variety	S 17 (1st ratoon)	S 17 (1st ratoon)
Spacing between cane rows	Alternately 227 cm and 97 cm	Alternately 227 cm and 97 cm
Rows of rice planted in every 227 cm cane inter-row	4 rows, 9 m long and 20 cm apart	4 rows, 9 m long and 20 cm apart
Irrigation	Overhead, 18 mm/3 days	None
Planting dates		
First	9 September, 1976	1 December, 1976
Second	1 October, 1976	15 December, 1976

TABLE 2. Grain yield and other characteristics of rice in inter-rows of sugarcane ratoons — Fuel and Belle Vue Harel

Variety	Yield* (kg/ha)		Days to 50% flowering	
	Fuel	Belle Vue	Fuel	Belle Vue
IR 532 E 420	522	84	99	98
YRL	413	110	105	88
TN1	246	13.5	115	103
TN1 (transplanted)	297	—	82	—
ANOVA	**			
LSD 0.05	91			
CV %	20			

* *At 12% moisture content. Twenty six per cent of the sugarcane field was used for rice cultivation.*

TABLE 3. Cane and sugar yields at Fuel

Treatments	Sugarcane yield (tons/ha)	I.R.S.C.	Sugar yield (tons/ha)
Control	92.0	12.00	11.0
IR 532 E 420	106.6	11.97	12.7
YRL	100.2	11.38	11.3
TN1	106.4	11.38	12.0
TN1 (transplanted)	101.2	11.43	11.3
ANOVA	n.s.	n.s.	n.s.
CV %	19.5	9.7	16

FIGURE 1. Shading of rice before maturity in inter-rows of sugarcane spaced at 1.5 m

FIGURE 2. Rice planted in 227 cm inter-row of 1st ratoon sugarcane in pineapple planting arrangement (227 cm x 97 cm). Note that cane trash is kept in the 97 cm inter-rows.

Results of the second experiment (Table 4) showed that *Kwang Loo* and *Red Plum Zao* had short growing cycles and matured well before the cane canopy had covered the inter-rows (Fig. 2). *Kwang Loo* yielded slightly less than *Red Plum. Chan Chui No. 11,* a potentially high yielder, had a comparatively longer growing cycle and did not reach maturity before being over shadowed by the cane canopy. A comparison of rice yields obtained under the two moisture conditions clearly showed, as expected, inferior yields in grain under rainfed condition. That was probably due to an irregular rain distribution during the growing season. The rice plants sometimes exhibited stress symptoms. *Red Plum* and *Kwang Loo* showed promise for cane inter-row cultivation under both irrigated and rainfed conditions.

TABLE 4. Grain yield and other characteristics of rice varieties in inter-rows of sugarcane ratoons — Fuel and Benares

Variety	Yield (t/ha)*		Days to 50% flowering		Plant height (cm)	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
			Fuel (irrigated)			
Kwang Loo	1.4	1.0	83	80	50	52
Red Plum Zao	1.6	0.2**	89	85	58	59
Chen Chui No. 11	1.6	0.2**	97	97	68	70
			Benares (rainfed)			
Kwang Loo	0.8	0.8	79	76	65	67
Red Plum Zao	0.9	0.8	79	76	68	71
No. 60	0.5	0.6	68	62	49	55

* *At 12% moisture content. Twenty-six percent of the sugarcane field was used for rice cultivation.*

** *Severely damaged by birds.*

CONCLUSIONS

1. The rapid growth of ratoon canes with the conventional row spacing of 1.5 m in Mauritius, limits the period that may be used by a rice crop in the inter-rows, to approximately 105 to 110 days.

2. Rice variety TN1, commercially used in paddy fields, is too late maturing for upland cultivation in sugarcane inter-rows.

3. The wider cane interrows (227 cm) are well suited for a rice crop. Short-cycle varieties, such as *Red Plum* and *Kwang Loo*, are suitable as inter-crops with yields up to 1.6 tons/ha under irrigated conditions.

4. Rice yields under rainfed conditions are inferior to yields under irrigated conditions.

INTERCALADO DE UN PRIMER RETOÑO DE CAÑA DE AZUCAR CON ARROZ EN MAURICIO

A. R. Pillay

RESUMEN

Se emprendio un estudio para investigar la posibilidad de intercalar caña de azucar en retoño con arroz. Se obtuvieron rendimientos muy bajos con las variedades de arroz utilizadas en campos inundados en Mauricio, cuando se intercalo como arroz en secano entre las hileras de caña de azucar sembrada al espaciamiento convencional entre hileras de 1.50 m. El arroz intercalado no afecto adversamente de manera significativa los rendimientos de azucar. Se obtuvieron rendimientos de hasta 1.6 ton/ha con variedades de arroz de ciclo corto sembrado cada segunda hilera (227 cm) de caña de primer retoño en niembra tipo "piña" (227 cm y 97 cm) bajo riego y hasta 0.9 ton/ha en secano.

GERMINATION RESPONSE OF SUGARCANE CULTIVARS TO SOIL MOISTURE AND TEMPERATURE

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ABSTRACT

Responses of four sugarcane cultivars, F 178, 67-9, 69-463 and 70-5122, to soil moisture and temperature were investigated. In the soil moisture experiment, four soil matric potentials of −0.3, −3, −15 bars and saturation were maintained and the temperature was kept at 28° C for germination. For the temperature experiment, air temperature was kept at 30, 26, 22 and 18° C, and soil moisture was maintained at −0.3 bars.

The optimum soil moisture and temperature for germination was −0.3 bars and 30° C, respectively. The rate and total germination of all cultivars declined with decreasing soil matric potential through its effects on water availability and the rate of water movement. No germination was found at saturation due to the lack of oxygen. The germination rate also decreased with decreasing temperature, at least 36 days were needed to obtain 50% germination at 18° C in comparison to 8 days at 30° C. The final germination was affected less by low temperature than was the germination rate.

Different responses in germination to moisture and temperature were found between cultivars. The order of cultivars with respect to their capacity to germinate against environmental stress was F178 > 67-9 > 69-463 > 70-5122. Recommendations to increase germination in field practice are given.

INTRODUCTION

Soil moisture and temperature are recognized as the two most important environmental factors affecting germination of seed cuttings under Taiwan's climatic condition. Recent experimental results showed that germination reduced as the soil matric potential decreased through its effects on water availability and rate of water movement (Hadas and Russo[4]; Yang and Chen[15]). In the wet range, germination also decreased due to lack of oxygen (Dasberg and Mandil; Yang and Chen[15]). The optimum temperature for sugarcane germination is in the range of 32 and 38°C (Barnes[1] and Humbert[5]). The lower the temperature, the slower the germination rate and thus the greater the chance of disease organism having access to the cuttings, resulting in high mortality of buds (Barnes and Humbert[5]).

Evidence showed the varietal differences in the response of germination to temperature and soil moisture. Since the germination of sugarcane cuttings is extremely important to achieve successful crop production, the germination characteristics of every commercial cane variety should be evaluated so as to find a suitable management method for obtaining an adequate crop stand. The purpose of this study was to determine the response of one newly released cane variety and three cultivars to soil matric potential and temperature. The management method which can be used for promoting emergence rate and final germination of those cultivars are also discussed.

MATERIALS AND METHODS

Healthy and uniform one-eye seed cuttings of commercial variety F178, and cultivars 67-9, 69-463 and 70-5122 were selected and placed horizontally in a germination box measuring 40 cm (wide) x 60 (long) x 10 (high). Ten cuttings were used for each cultivar in every replication. The seed cuttings were covered with 1.5 cm of soil. The soil used was a clay loam containing 35% clay, 35% sand and 30% silt.

This study was divided into two. In the first part, the soil moisture effects were evaluated. Four levels of soil matric potential, −0.3, −3, −15 bars and saturation were achieved by putting the soil in a soil moisture extractor set at the desired pressures (Richard[9]). To cut down the surface evaporation so as to maintain a reasonably constant soil moisture regime, the soil surface was covered with a sheet of polyethylene film punched with tiny holes. The experiment was arranged in a split design with the soil moisture as main plot and the cultivar as subplot. After planting, the germination boxes were placed in growth chamber with air temperature controlled at 28°C and humidity at 75%. In the second part of the experiment, the soil moisture was kept at −0.3 bars and four temperatures: 30, 26, 22 and 18°C were maintain in the growth chamber. The remaining procedures were the same as in the first part. Counts of emergence were made every day during the germination period to determine the rate and the germination percentage.

RESULTS AND DISCUSSION

Soil Moisture Effect

The germination rate of four sugarcane cultivars in clay loam soil at defined soil matric potential are presented in Fig. 1. The results indicate clearly that the optimum soil moisture for cane bud germination is in the range of field capacity or −0.3 bars of matric potential in this study. As the soil moisture potential decreased, the rate and final percentage of germination were lowered. At −0.3 bars, more than 80% of buds germinated. At −3 bars or roughly 50% of the available range, the final germination percentage was in the range of 10 to 100%. At −15 bars, or so called permanent wilting point, except for F178, all other cultivars had a germination less than 60%. Recent studies pointed out that matric potential influences germination not only by its effects on water availability but also by means of hydraulic conductivity of soil and

by its effect on seed sett-water contact (Collies Hector[2], Hadas and Russo[4], William and Shaykewich[14], Yang and Chen[15]). The quantity and the rate of water movement from the soil into the seed sett should be fast enough to meet the requirement of the germinating buds. When soil matric potential decreases, the hydraulic conductivity decrease drastically[4]. As a result, the rate of water movement in the soil, across the seed cutting-soil interface and in the seed piece is reduced. The lack of moisture would retard the bud transition from dormancy to activity (Mayer and Poljakoff-Mayber[7], Wanjura and Buxton[12], Yang and Chen[15]). In the extreme case at −15 bars matric potential or lower, a reverse moisture gradient might even be created. The moisture flow direction could shift from seed piece into soil.

Under saturated conditions, no germination was observed for all the cultivars tested during the 25 days germination period. Such germination failure is mainly caused by lack of oxygen. It is well known that germinating seeds have rapid respiratory activity (Stiles[11]). The limited oxygen in soil can be consumed in a relatively short time. Since the supply of oxygen from atmosphere to soil is mostly by the diffusion process and such process is impaired because of a thick water film (Barnes[1], Dasberg and Mendel[3]) the germination is delayed or fails due to the lack of oxygen supply. This aerobic condition affects germination more seriously than the moisture stress. Similar conclusions were also drawn by McMartin[8] in South Africa.

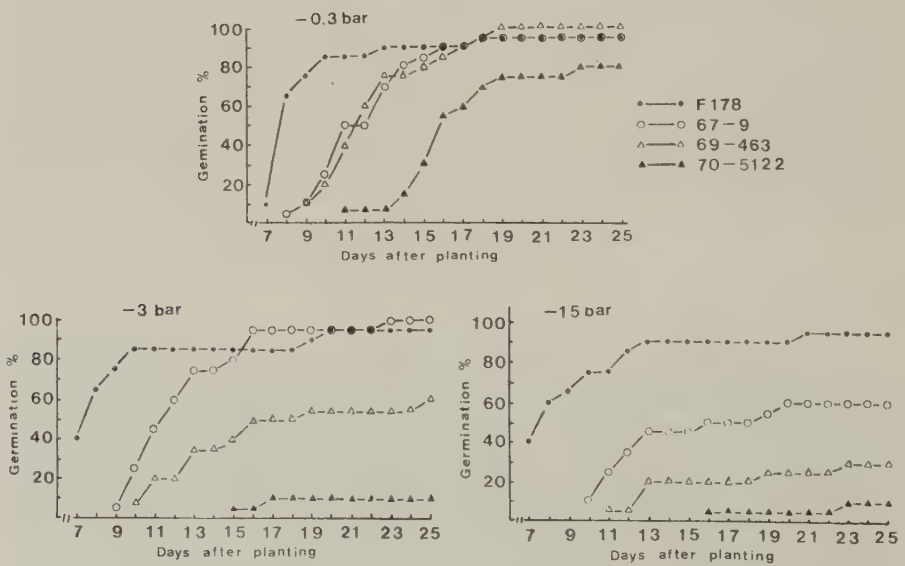

FIGURE 1. Germinations of sugarcane seed cutting at −0.3 bars −3 bars and − 15 bars.

A wide difference in the germination response of sugarcane cultivars to soil moisture was observed in this experiment (Fig. 1). At all matric potentials, F178 had the most rapid and highest total germination compared with other cultivars. Less than 8 days were needed for F178 to obtain 50% germination and at very dry condition of −15 bars, 95% germination percentage was obtained. Such results indicate that this variety is able to adapt to a quite wide range of soil moisture regime. In contrast to F178, cultivar 70-5122 was the poorest among the four cultivars under all soil moisture levels. At the optimum soil moisture for germination of −0.3 bars, only 80% of the buds germinated. When the matric potential decreased to −3 bars a drastic reduction of 10% in germination resulted. Although cultivars 67-9 and 69-463 could achieve very good final germination percentage, they have a slower germination rate and were sensitive to soil moisture stress. The difference in response of germination to soil moisture between cultivars could be attributed to: (1) different hydraulic conductivity of epidermis and rind causing a different rate of water uptake by seed setts, (2) different quantity of water required to activate enzymes and to invert sucrose, and (3) different concentration of sucrose and reducing sugar in the seed cutting (different osmotic potential of cane juice). The exact reasons can not be evaluated from the results of this experiment. Further studies are needed.

Effect of Temperature

As shown in Fig. 2, the germination rate of sugarcane buds decreased as the temperature lowered. About 8 days were needed for 50% germination at 30°C for all cultivars tested. At 26°C, 8 to 25 days were needed and when temperature further decreased to 18°C, 36 days were recorded for F178 and 67-9. The cultivars of 69-463 and 70-5122 never reached 50% germination even at 80 days after planting.

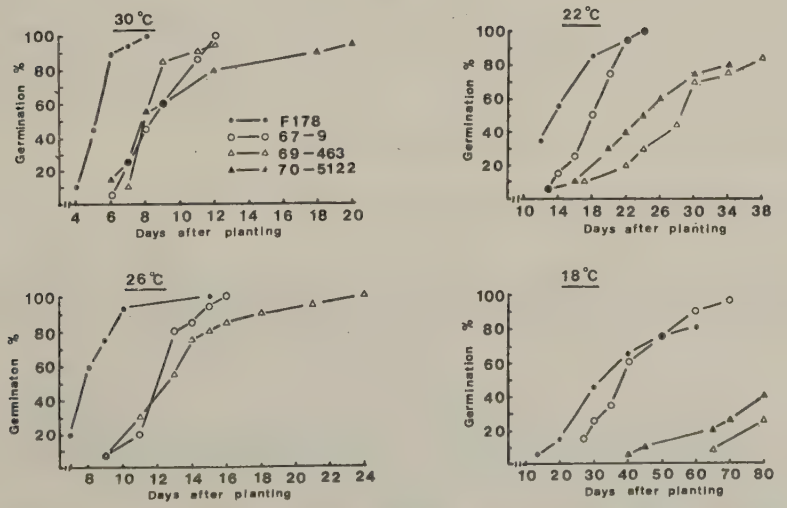

FIGURE 2. Germination of sugarcane seed cutting at 30, 26, 22 and 19°C.

The final germination percentage was not so sensitive to temperature as was the germination rate. All the cultivars had more than 80% germination within 35 days when the temperature was higher than 22°C. Temperatures below 20°C inhibit germination. Only 40 and 25% final germination was observed for cultivars 70-5122 and 69-463, respectively. Higher temperatures could accelerate the rate of water absorption by seed or bud Sorrells and Pappelis[10], Wanjura and Buxton[12], and thus speed up the rate of germination. When the temperature decreased to a certain level, not only did the rate of water uptake by seed cuttings decrease because of the increase in resistance to water flow, the activity of enzymes involved in the germination mechanism may also slow down (Sorrels and Pappelis[10], Stiles[11], Wanjura and Buxton[2]). Sometimes inhibitors might be formed resulting in the declining germination rate (Went[13]).

Similar to the response to soil moisture, F178 was the most insensitive to temperature followed in the order of 67-9, 69-463 and 70-5122. The difference in sensitivity to temperature between cultivars is related to the genetic variability which in turn is associated with enzyme activity (Mayer and Poljakoff-Mayber[7], McMartin[8], Went[13]). By using the concept of seed vigor, such genetic variability of germination can be expressed quantitatively. Emergence rate (ER) which is used as the expression of seed vigor, was defined as the summation of the quotients of number of emergence/number of the day at which the count was made (Maguire[6]). Arithmetically it can be expressed as.

$$ER = \frac{\text{First bud emerged}}{\text{Days after planting}} + \ldots\ldots\ldots\ldots + \frac{\text{Last bud emerged}}{\text{Days after planting}}$$

Results of ER at different temperatures for four cultivars are given in Table 1. The data shows that F178 had highest emergence rate at all temperatures. The ER of cultivar 70-5122 was lowest at 30°C but in the lower temperatures of 22 and 18°C, it had a higher ER than 69-463. A lower value of ER means intolerant to low temperature. Under Taiwan's cultivation system, cultivars 69-463 and 70-5122 are not suitable for spring planting. The coldest months of February should also be avoided for ratooning.

Cultivation Methods for Promoting Germination

To achieve a satisfactory and fast germination of cane seed pieces under field condition, especially for moisture and temperature-sensitivity varieties such as 69-463 and 70-5122, the following recommendations are given.

(1) Surface drainage is extremely important for the germination of autumn-planted cane. Land grading and smoothing are needed to remove tillage irregularities and depressions. Excess water should be drained in a short period after heavy rain during the planting time.

(2) A good seed bed preparation is required for moisture-sensitive

TABLE 1. Comparison of emergence rate among four cultivars at different temperatures.

Cultivars	Temperatures °C			
	30	26	22	18
F178	3.67	2.34	1.41	0.58
67-9	2.26	1.57	1.12	0.49
69-463	2.27	1.47	0.66	0.07
70-5122	2.12	–	0.73	0.13

varieties in order to have optimum soil moisture regimes for seed cuttings and to have good piece-soil contact.

(3) Moisture-sensitive varieties should be planted in medium-textured soils, while coarse and fine-textured soils should be avoided if possible.

(4) Before planting, the cuttings of moisture and temperature-sensitive varieties should be soaked in water or lime water for one to two days to stimulate germination.

(5) In coarse-textured soils, irrigation should be applied right after planting, but in fine-textured soil, the cuttings should be planted three to four days after irrigation.

(6) Temperature-sensitive varieties should not be used for spring-planting. If planting during spring is unavoidable, soil surface can be covered with polyethylene film to raise the temperature.

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RESPUESTAS DE CULTIVARES DE CAÑA DE AZUCAR EN GERMINACION A HUMEDAD DEL SUELO Y TEMPERATURA

Sung-jen Yang y Jung-bin Chen

RESUMEN

Se investigo la respuesta de cuatro cultivares de caña de azucar,

F178, 67-9, 69-463 y 70-5122 en relacion a humedad del suelo y temperatura. En el experimento de humedad del suelo, cuatro potenciales se mantuvieron, −0.3, −3, −15 barras y saturacion, y se mantuvo la temperatura en 28° C para germinacion. En el experimento de temperatura se mantuvieron las siguientes temperaturas: 30, 26, 22 y 18° C, con una humedad de suelo de −0.3 barra.

Los resultados mostraron que la optima humedad del suelo y temperatura para germinacion fue −0.3 barra y 30° C respectivamante. La tasa y total de germinacion de todos los cultivares disminuyo a medida que bajaba el potencial de humedad debido a sus efectos sobre la disponibilidad de agua y la repidez con que esta se movia. No hubo germinacion al estar saturado el suelo debido a la falta de oxigeno. La tasa de germinacion tambien disminuyo a medida que bajaba la temperatura, haciendo falta por lo menos 36 dias para lograr una germinacion de 50% a 18° C en comparacion con 8 dias a 30° C. La germinacion total fue menos afectada que la tasa de germinacion por las bajas temperaturas.

Se encontraron diferentes respuestas en germinacion a humedad y temperatura entre los cultivares. Los cultivares se ordenan de la siguiente manera en cuanto a su capacidad para germinar bajo tensiones ambientales: F178 > 67-9 > 69-463 > 70-5122. Se dan recomendaciones de practicas de campo para aumentar la germinacion.

SUGARCANE STALK DISTRIBUTION IN TWO ROW SPACINGS

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ABSTRACT

Studies on sugarcane *(Saccharum spp.)* grown in 0.5 and 1.5 m row spacings for biomass production, were conducted at Belle Glade, Florida. The main objectives of this study were to analyze the stalk distribution in two row spacings and to demonstrate the applications of the stalk distribution analysis. Stalk population, length, and height were monitored monthly. The maximum stalk population in the 0.5 m row spacing was reached in May and then dropped by about 7, 49, 15, 5, 2, and 3% in June, July, August, September, October, and November, respectively. The ratio of stalk populations in the 0.5 and 1.5 m spacings varied from 2.88 in May to 1.15 in November. Stalks in the 0.5 m rows were longer and taller by about 10 and 39% as compared to 1.5 m row spacing. Stalks were more erect in 0.5 m row spacing from May to August. Monthly stalk length population was simulated well by the Log Pearson Type III (LPT) distribution. The results of LPT distribution analysis can be used to modify the estimation of stalk length, to choose a proper sample size within each interval of stalk length, to avoid using samples of extreme values, and to study sugarcane growth dynamics.

INTRODUCTION

Recent studies have indicated the potential of sugarcane as a renewable source of energy (Lipinsky[3]). Since sugarcane produces more biomass per unit area and time than any other crop presently grown, it is the prime candidate for research for its potential as a source of energy. One of the most promising ways of increasing the biomass per unit area is to increase stalk density through closer row spacing. A pattern of stalk elongation in different row spacings which includes stalk length, height, lodging (horizontal projection), and erectness has not been studied by previous researchers. The stalk elongation pattern is an important factor to be considered in cultural practices including weed control, time of harvesting, harvestor design, and plant growth.

The purposes of this study were:

1. to determine the monthly sugarcane stalk population in two row spacings;

2. to estimate and compare stalk length, height, erectness and lodging in two row spacings;

3. to analyze stalk length distribution as a probability density function; and

4. to discuss the applications of stalk length distribution.

MATERIALS AND METHODS

Sugarcane was grown in a field located at Belle Glade, Florida, on muck soil. A narrow row spacing of 0.5 m was compared with the conventional (wide) row spacing of 1.5 m in four blocks a randomized complete block design. Each block was 33.5 x 24.4 m. The insecticide Furadan was placed in the furrow at a rate of 0.5 kg per 33.5 m of row to control wireworms. Fertilizer was broadcast at a rate of 800 kg/ha of 0-8-45 with 0.5, 1, 0.5, 0.5, percent of Cu, Mn, Zn, and B, respectively. Weeds were controlled by application of Randox and Atrazine at 3 weeks, spot treatment with Silvex and Dalapon, and by hoe as required. Insects and rats were also controlled with pesticides as required. The water table was maintained at a depth of approximately 45 cm below the ground surface. Cane variety CP 65-357 was planted in December, 1976. Due to the freezes of January and February, 1977, the young cane was frozen to ground level. Skips greater than 1 meter were replanted in March, 1977.

Sampling Procedures

Stalk length between the soil surface and top visible dewlap (TVD) was measured monthly from May through August, 1977.

Stalk vertical height between the soil surface and the TVD were also measured when stalk length was measured.

The "grand period" for Florida sugarcane is approximately 7 months, April through October. Therefore, the most stalk length measurements were taken during that period. The measurements were taken on the first week of the month. No data were collected in April because the sugarcane had just started to grow after the March replanting. Most of the cane had reached full growth and was badly lodged by September, therefore, stalk length was extremely difficult to measure. Stalk length and height were not measured after August except that the monthly populations were monitored through November.

Description of Models

From the data collected on various growth parameters the following models are proposed:

Model A — Sugarcane Erectness

Sugarcane stalk elongation can be expressed as in Figure 1, where X_1 is the stalk length between the ground surface and the TVD, X_2 is the stalk height between the ground surface and the TVD, X_3 is the lodging of the stalk, θ_1 is the inclination angle between the stalk and the ground surface and θ_2 is the erectness. Only the X_1 and X_2 are measured, θ_1, θ_2, and X_3 were computed as:

$$\theta_1 = \sin^{-1}(X_2/X_1) \quad (1)$$

$$\theta_2 = 90^\circ - \theta_1 \quad (2)$$

and

$$X_3 = X_1^2 - X_2^2)^{0.5} \quad (3)$$

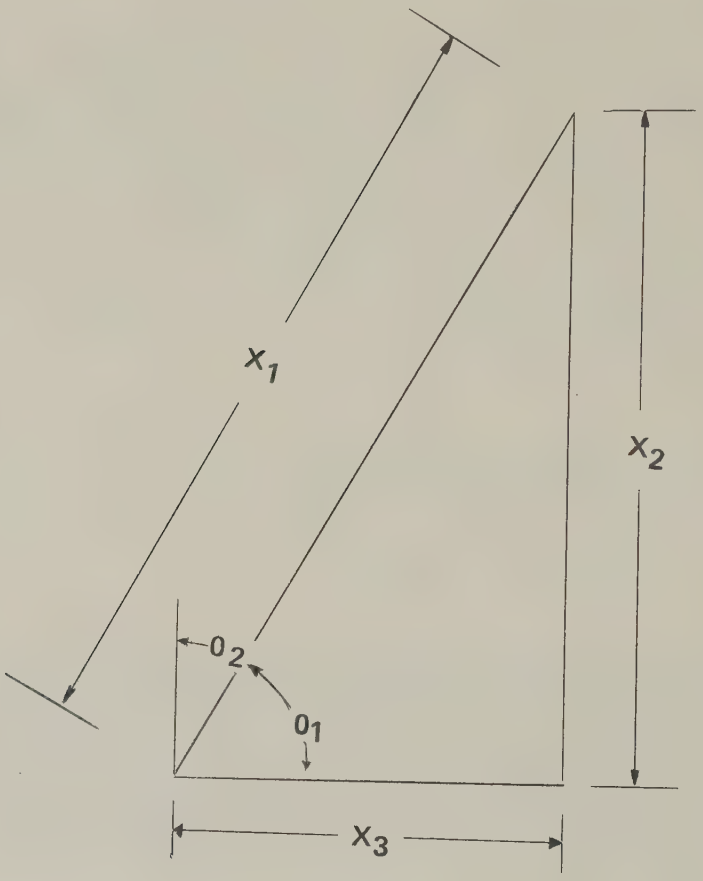

FIGURE 1. Sugarcane stalk elongation

The differences in X_1, X_2, X_3, and θ_2 between the 0.5 and 1.5 m row spacings were discussed based on two statistical parameters of mean and standard deviation.

Model B – Sugarcane Stalk Length Distribution

Shi and Gascho's[5] data on stalk population and leaf area index (LAI) of cane are shown in Table 1. The LAI in May were 1.86, and 0.43 for 0.5 and 1.5 m row spacings, respectively. The LAI in June increased to 7.44 and 2.54 for 0.5 and 1.5 m row spacings, respectively. Due to this high growth rate and plant competition, the taller cane can absorb more and more solar energy to grow and the smaller cane is getting less and less. Therefore, the range of sugarcane stalk length varied widely and the distribution was very unsymmetrical at a particular time. Thus, another probability distribution function to analyze the stalk growth density was to be employed besides the normal distribution function.

TABLE 1. Sugarcane stalk population and leaf area index in two row spacings

Month	Row spacing	Stalk population monthly	Changes in population monthly	Ratio between two row spacing	LAI
	m	1000/ha	%		
May	0.5	417	–		1.86
	1.5	145	–	2.88	0.43
June	0.5	387	– 7		7.44
	1.5	197	36	1.96	2.54
July	0.5	184	–49		6.10
	1.5	140	–29	1.31	4.19
August	0.5	122	–15		5.02
	1.5	95	–23	1.28	3.78
Sept.*	0.5	100	– 5		ND
	1.5	82	– 7	1.22	ND
Oct.	0.5	91	– 2		ND
	1.5	79	– 2	1.15	ND
Nov.	0.5	79	– 3		ND
	1.5	70	– 5	1.13	ND

* *Data of September, October and November were not shown in the paper given by Shih and Gascho*[5].

A series of probability functions to fit virtually any distribution was derived by Pearson[4] and was described in detail by Elderton[2]. The general and basic equation to define the probability density of a function so called Pearson distribution is:

$$p(x) = \text{Exp}\int_{-\alpha}^{x} (a + x)/[(b_0 + b_1x + b_2x^2)dx] \qquad (4)$$

where a, b_0, b_1 and b_2 are constants and x is a random variable. The criteria for determining types of distribution are B_1, B_2 and k being defined as follows:

$$\beta_1 = \mu_3^2/\mu_2^3 \qquad (5)$$

$$\beta_2 = \mu_4/\mu_2^2 \tag{6}$$

and

$$k = \frac{\beta_1 (\beta_2 + 3)^2}{4(4\beta_2 - (3\beta_1)(2\beta_2) - 3\beta_1 - 6)} \tag{7}$$

where μ_2, μ_3 and μ_4 are the second, third, and fourth moments about the mean.

With $\beta_1 = 0$ and $\beta_2 = 3$, the resulting Pearson distribution is identical with the normal distribution. For Type III, $k = \infty$ or $\beta_2 = 1.5\beta_1 + 3$, are skewed, usually bell-shaped but may be J-shaped. Its probability density with the origin at the mode is

$$p(x) = p_0 \left(1 + \frac{x}{a}\right)^c \text{Exp}(-cx/a) \tag{8}$$

$$c = \frac{4}{\beta_1} - 1 \tag{9}$$

$$a = \frac{c}{2}\frac{\mu_3}{\mu_2} \tag{10}$$

$$p_0 = \frac{N}{a} \frac{c^{c+1}}{e^c \Gamma (c + 1)} \tag{11}$$

where $\Gamma (c + 1)$ = Gamma function of $(c + 1)$; and

N = total frequency

The statistical parameters are: mean = mode $- \mu_3/2\mu_2$; standard deviation $= \sqrt{\mu_2}$; and Pearson's Skewness $= \sqrt{\beta_1/2}$.

The Log Pearson Type III distribution (LPT) which is obtained when the logs of observed data are used along with the Pearson Type III distribution as given in Equation 4. Three basic statistical parameters comprised of $\log_{10}$ of mean, standard deviation, and skewness coefficient for the observation data are required to compute the result of the model.

RESULTS AND DISCUSSIONS

Stalk Population

The monthly stalk population and the ratio between the two row spacings was plotted in Figure 2. The monthly changes are listed in Table 1.

Based on Figure 2 and Table 1, the following observations were made:

1. The maximum population in the narrow spacing was reached in May and then dropped by about 7, 49, 15, 5, 2, and 3% for June, July,

August, September, October, and November, respectively. The reason for this extensive stalk population decline was the high LAI (7.44) in June which restricted the even distribution of solar energy to each stalk, and plant competition as a result of which about 50% of the small stalks decayed.

2. The maximum stalk population in the wide row spacing was reached in June instead of in May as in the narrow spacing. The LAI for May in the wide row spacing was 0.43 (Table 1). This allowed a high proportion of vacant space for absorbing solar energy to initiate new stalks. This was not true in the narrow spacing where the LAI was 1.86.

3. After the maximum stalk population was reached in June in 1.5 m row spacing, it fell by about 29, 23, 7, 2, and 5% for July, August, September, October, and November, respectively. Up to the month of August about 52% of the small stalks in the wide row spacing had decayed as compared with 71% for the narrow spacing.

4. The stalk population was nearly stabilized after August, i.e. the monthly decay rate was reduced to 2 to 7%.

5. The ratio of stalk population of the narrow row spacing to the wide row spacing decreased sharply from 2.88 in May to 1.31 in July.

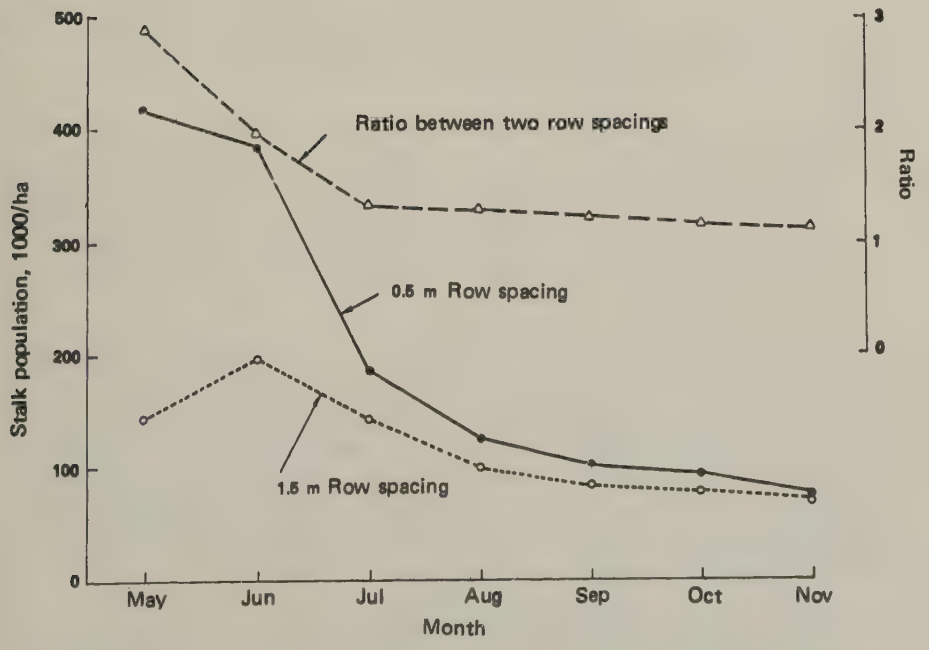

FIGURE 2. Sugarcane stalk population with time in two row spacings.

Stalk Elongation

A total of 8047 measurements of both monthly stalk length and height in two row spacings were made and the analysis of the data are listed in Table 2. Erectness was computed based on the methods described in Equations (1) and (2). The mean values, standard deviation, and F-values for stalk length, height and erectness are all given in Table 2. The following observations can be drawn:

1. Stalk lengths in the 0.5 m row spacing were greater than in the 1.5 m row spacing. The differences were 20% in May, 38% in June, 22% in July, and 10% in August. The LAI in the narrow row spacing was much higher than in the wide row spacing (Table 1). One reason for the longer stalks in the narrow row spacing was the plant competition for space and sunlight. A second reason was the 36% increase in new stalks in the wide row spacing with a 7% loss of small stalks in the narrow row spacing for the month of June. Since stalk length from newly initiated stalks was less than from the old stalks, the total stalk length with both old and new stalks together as in wide row spacing was much less than the length of only older stalks as in the narrow spacing. The difference in August was only 10% indicating a stabilization of stalk population.

2. The stalk heights in the 0.5 m row spacing were all greater than in the 1.5 m row spacing. The difference varied from 27, 39, 23, and 10% in May, June, July, and August, respectively. The reason for the latter stalks in the narrow row spacing could be interpreted as the same reason given for increased stalk length.

3. Cane in the narrow row spacing was more erect than in the wide row spacing for May, July and August. The reason was due to the plant competition for the limited solar energy available and the limited space for growing. The difference in erectness was not significant in June because about 36% of the stalks that were growing in the wide row spacing were relatively young and were not only shorter but also more erect.

The mean values, standard deviation and F-test values for sugarcane stalk lodging are listed in Table 3. The stalk lodging for May, July, and August indicating larger degree of inclination in the wide row spacing. The result of June was not significant. However, a symptom was observed that the cane in the narrow rows lodged more at the end of the season. The LAI for narrow row spacing was near 2 in May and contributed to the natural biological competition system for controlling weeds. This significant contribution was verified by field observations.

Probability Functions for Stalk Length Distribution

The statistical parameters of stalk length used for the LPT distribution

TABLE 2. Monthly sugarcane stalk length, height, and erectness in two row spacings.

Month	Row spacing	Sample sizes	Stalk length, X_1			Stalk height, X_2			Stalk Vertically, O_2		
			Mean	Std. dev.	F value	Mean	Std. dev.	F value	Mean	Std. dev.	F value
	—cm ——		——— cm ———			——— cm ——			—— degree ———		
May	50	1321	20.9	9.4	99**	19.9	9.5	156**	15.1	12.4	182**
	150	1152	17.5	7.7		15.7	7.1		22.4	14.5	
June	50	1032	61.7	41.0	163**	61.3	41.1	165**	5.0	7.5	1
	150	1600	44.7	27.2		64.2	27.2		5.3	7.9	
July	50	504	136.4	57.2	68**	136.0	57.3	72**	2.1	5.9	55**
	150	1182	111.9	55.1		110.9	54.9		4.8	7.3	
August	50	364	227.0	37.7	67**	226.5	37.4	70**	1.9	3.4	40**
	150	892	206.1	42.3		205.1	42.4		3.6	4.6	

***F-test between two row spacings is significant at 0.001 level.*

TABLE 3. Sugarcane stalk lodging by month for two row spacings.

Month	Row spacing	Mean	Std. dev.	F value
		cm		
May	50	4.8	4.2	64**
	150	6.3	5.2	
June	50	3.6	5.1	0
	150	3.5	5.4	
July	50	3.8	8.8	47**
	150	8.2	13.1	
August	50	7.1	12.8	30**
	150	12.3	16.1	

***F-test is highly significant at 0.001 level.*

are listed in Table 4. Both the observation data and the prediction curve for the LPT distribution are plotted in Figures 3, 4, 5, and 6 for May, June, July, and August, respectively. Some observations and interpretations can be made from the figures.

1. The stalk length distribution data plotted on log probability paper was not a straight line. This implies that the monthly stalk length distribution was neither a normal nor a log normal distribution (Aitchison and Brown[1]). Thus, other types of distribution functions were investigated.

TABLE 4. The statistical parameters of sugarcane stalk length for the Log Pearson Type III Distribution.

Month	Row spacing	Log mean	Log std. dev.	Log coeff. skew
		cm		
May	50	1.2695	0.2226	−0.5837
	150	1.1957	0.2104	−0.5957
June	50	1.6863	0.2776	−0.3043
	150	1.5676	0.2776	−0.3043
July	50	2.0710	0.2716	−1.3637
	150	1.9591	0.3211	−1.0294
August	50	2.3488	0.0827	−1.5379
	150	2.2999	0.1267	−3.3167

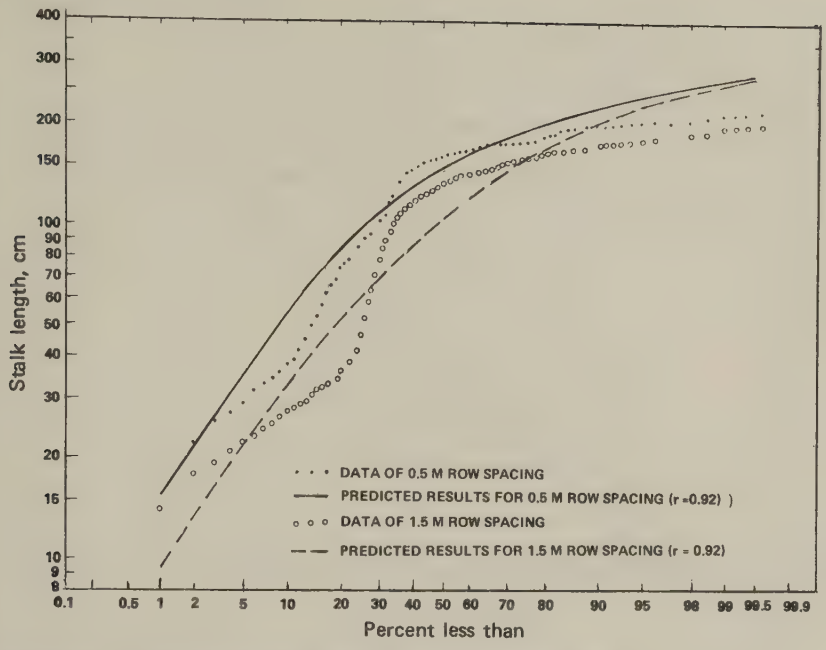

FIGURE 3. Sugarcane stalk length distribution for May.

2. The LPT distribution was well adapted to study the monthly stalk length distribution in two row spacings because the r values were all greater than 0.92 between the observed and the simulated data.

3. When the stalks were new growing or stabilizing conditions, the r values were high. For example, the young stalks in May for both row spacings were predicted with $r > 0.99$. Meanwhile, the stabilized stalks in August were also well predicted with $r > 0.98$.

4. When the stalks were mixed (both growing and decaying conditions), the r values were slightly lower. For example, the stalks in June and July for narrow row spacing and July for wide row spacing belonged to this mixed condition.

Application of Log Pearson Type III Distribution

Based on the results of satisfactory predictions in LPT distributions, some skewness in stalk length population does exist. Thus, four aspects should be considered in studying the characteristics of sugarcane stalk length.

First, the mean value based on a 50% chance of distribution is different from arithmetic average. Comparison of the arithmetic mean of stalk length with the 50% chance of LPT distribution are shown in Table 5. The percent of deviation between the two methods is also listed in Table 5 and varied from 8 to 29%.

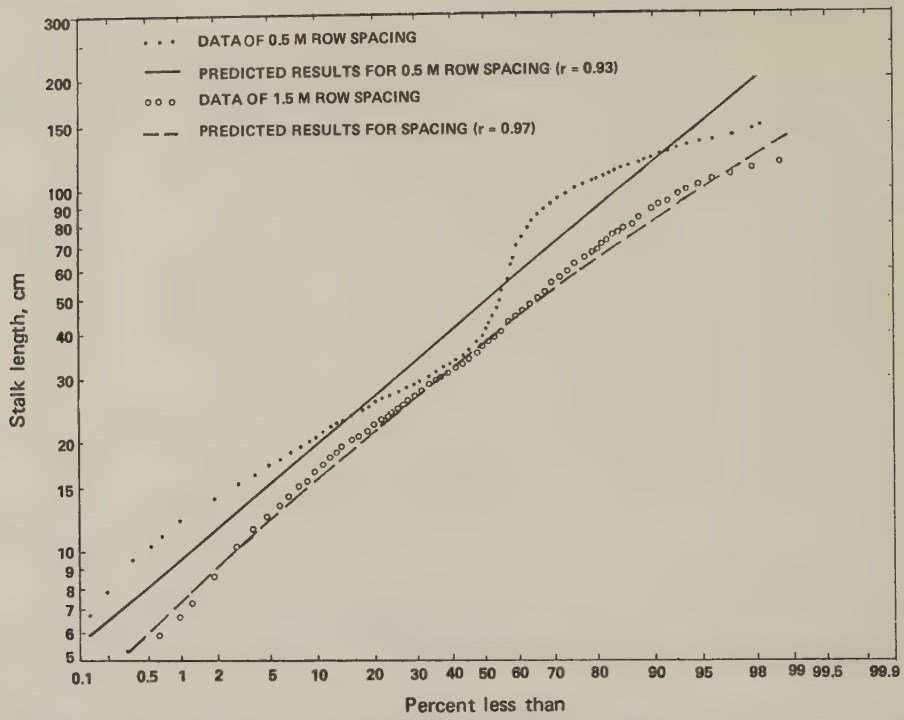
DATA OF 0.5 M ROW SPACING
PREDICTED RESULTS FOR 0.5 M ROW SPACING (r = 0.93)
DATA OF 1.5 M ROW SPACING
PREDICTED RESULTS FOR SPACING (r = 0.97)
Stalk length, cm
Percent less than

FIGURE 4. Sugarcane stalk length distribution for June.

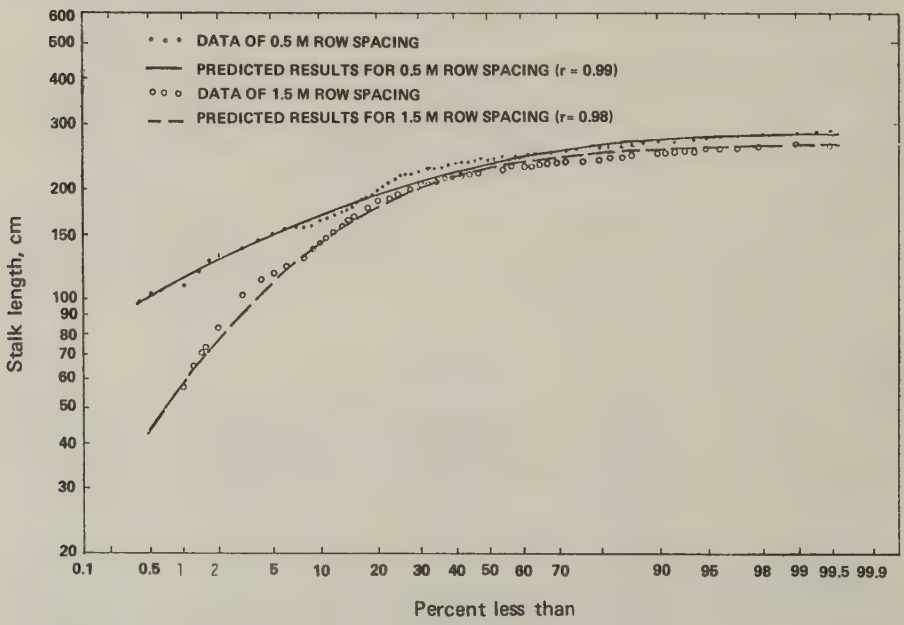
DATA OF 0.5 M ROW SPACING
PREDICTED RESULTS FOR 0.5 M ROW SPACING (r = 0.99)
DATA OF 1.5 M ROW SPACING
PREDICTED RESULTS FOR 1.5 M ROW SPACING (r= 0.98)
Stalk length, cm
Percent less than

FIGURE 5. Sugarcane stalk length distribution for July.

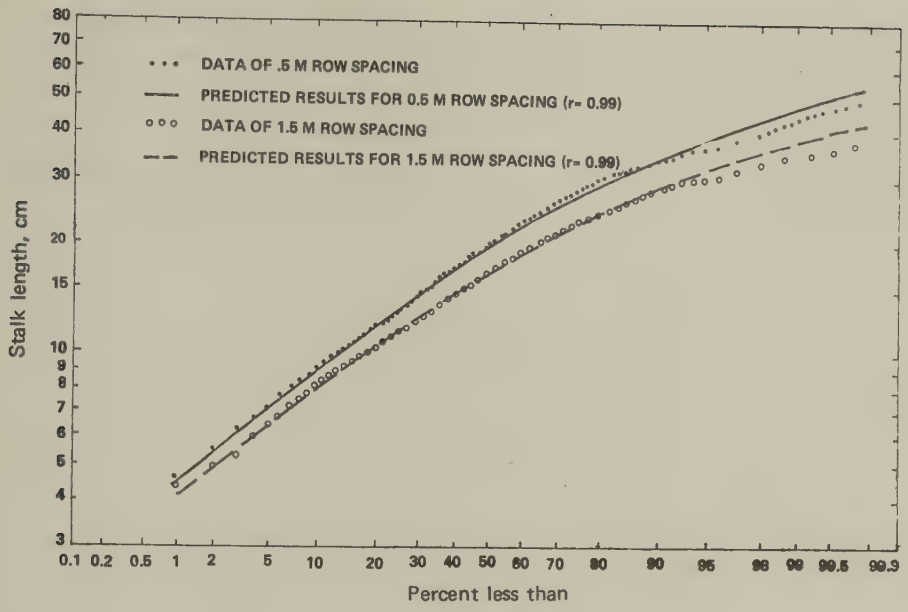

FIGURE 6. Sugarcane stalk distribution for August.

Second, the sample size within each interval should be based on the weighted percent of chance instead of on uniform selection. For example, the length of stalk in May for wide row spacing varied from 4 to 44 cm. If four intervals with 10 cm increments (designated as intervals 1, 2, 3, and 4) are chosen, then 20 samples are selected in each interval for the uniform chance method. However, the percent of chance in the LPT distribution is about 40, 42, 16, and 4% for intervals 1, 2, 3, and 4, respectively. Thus, the 80 samples distributed to intervals 1, 2 and 1, 2, and 4 are 32, 33, 13, and 3, respectively. There is a significant difference between these two methods. This implies that the sample technique based on the uniform chance to study the sugarcane stalk length characteristics can result in a biased conclusion.

Third, the results of LPT distribution can be used to avoid a sample which has an extreme value. For example, a stalk with a 50 cm length was discovered in May for the wide row spacing and the total sample size was limited to 80 stalks. The stalk was not sampled because its distribution is not more than one out of 1000 according to the probability shown in LPT distribution.

Fourth, the result of LPT prediction can be used to study sugarcane growth which includes stalk length, population function, stalk changing, growing and decaying characteristics.

TABLE 5. Comparisons of arithmetic mean of stalk length with 50% chance of Log Pearson Type III Distribution.

Month	Row spacing	Mean value of stalk length		Deviation
		Arithmetic	Log Pearson Type III	
	cm.	cm.	cm.	%
May	50	20.9	19.5	7.3
	150	17.5	16.5	5.8
June	50	61.7	48.5	27.2
	150	44.7	38.0	17.6
July	50	136.4	135.0	1.0
	150	111.9	103.0	8.6
August	50	227.0	234.0	3.1
	150	206.1	225.0	9.2

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DISTRIBUCION DE TALLOS DE CAÑA DE AZUCAR EN ESPACIAMIENTOS DE DOS HILERAS

S. F. Shih y G. J. Gascho

RESUMEN

Se llevaron a cabo estudios, en Belle Glade, Florida, con caña de azucar (*Saccharum* sp.), sembrada en hileras de 0.5 y 1.5 m,

para la produccion de biomasa. Los principales objetivos de estos estudios fueron; analizar la distribucion de tallos en espaciamientos de dos hileras y demostrar las aplicaciones del analisis de distribucion de tallos. Mensualmente se hacia un conteo de la poblacion de tallos, el largo y el alto. La mayor poblacion de tallos en el espaciamiento de hileras de 0.5 y 1.5 m se alcanzo en Mayo y luego callo alrededor de 7, 49, 15, 5, 2 y 3% en Junio, Julio, Agosto, Septiembre, Octubre y Noviembre, respectivamente. La proporcion de poblaciones de tallos en los espaciamientos de 0.5 y 1.5 m vario desde 2.88 en Mayo hasta 1.15 en Noviembre. Los tallos en las hileras de 0.5 m eran mas largos y altos por mas o menos 10 a 39% en comparacion con el espaciamiento de hileras de 1.5 m. Los tallos eran mas erectos en el espaciamiento de 0.5 m desde Mayo hasta Agosto. La poblacion mensual del largo del tallo fue bien simulada por la distribucion Log Pearson Tipo III (LPT). Los resultados de los analisis de distribucion LPT se pueden usar para modificar el calculo del largo del tallo, para escojer una muestra de tamano apropiado dentro de cada intervalo de largo de tallo, evitar usar muestras con valores extremos y estudiar las dinamicas del crecimiento de la caña de azucar.

STUDIES ON THE EFFECTS OF VARIOUS NITROGEN AND IRRIGATION LEVELS ON THE YEILD OF SUGARCANE VARIETIES BL. 4 AND L. 116

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ABSTRACT

The experiments were conducted to determine the relationship between irrigation and nitrogen requirements of sugarcane varieties BL. 4 and L. 116. Five nitrogen levels (0, 56, 112, 168 and 224 kg N/ha) and 5 irrigation levels were used (at coefficients of 0.6, 0.8, 1.0, 1.2 and 1.4 of pan evaporation). The calculated amount of water was applied with siphon pipes of known discharge at the given head of water.

The data on daily pan evaporation, tillering, cane weight, cane height and yield were recorded. Seventy-seven percent water was utilized up to mid-July and 50% was taken up during boom growth period from May to mid–July. Zero N at all irrigation levels reduced tillering. Different N levels did not improve tillering without adequate application of irrigation water. Larger N supplies ensured better early growth and increased yield by increasing cane weight and cane height. Nitrogen effects on cane yield were highly significant in both years. L. 116 did not require as much water and N to give optimum yield of cane as BL. 4. There was little effect of additional water at low N level, but yield increased with increasing water at high N level. However, yield increments at very high N levels resulted to additional cost of nitrogen. Marginal values of N and irrigation which defined a range of input combinations were calculated. On the whole, 112 kg N with irrigation supplies equivalent to pan evaporation seem to be a fairly good combination for both the varieties.

INTRODUCTION

Water and nitrogen are two essential inputs for sugarcane production in Pakistan. A close relationship exists between the continuous availability of soil moisture

and the response of crops to fertilizer (Bhatti and Azeem[2]). Insufficiency of irrigation water or nitrogen may depress yield, while the excess may not be economical either. If the amount of nitrogen is not in balance with the available irrigation water, nitrogen may leach down with excessive watering (Kemper *et al*[6]). Hence, it becomes increasingly important to determine the optimum amount of nitrogen in relation to the available supply of irrigation water. Increased water utilization by the cane crop has been reported when increased N levels are used (Reddy *et al*[7]). A dose of 150 kg N/ha significantly increased cane yield even higher (Singh & Singh[8]). Significant yield increases have been reported when extra irrigations were combined with additional doses of N. (Verma[9], Wali Yusuf[10]).

The crop has an optimum period of growth from May to September. During this time, the root system and the assimilation mechanism of the plant is very active. Over 50% of the potential evaporation or actual consumption of water for the whole growth period was from June to September (Chang and Wang[3]). Mean daily rates of water use have been reported to be highest in the pre-monsoon period and the total water requirements of the crop for two seasons being 1,805 and 1,884 mm (Cheema and Moonlani[4]). In some previous studies at Faisalabad, it was ascertained that 1,832 mm irrigation water was needed to meet the consumptive use requirements of 1,190 mm water for sugarcane (Anon[1]). Low irrigation level during the dry season reduced tillering and yield of cane (Gill[5]). It has been observed that liberal irrigation is most effective during pre-monsoon period, less during monsoon and have practically no effect during post-monsoon period (Wali and Yusuf[11]).

Little work has been done on the moisture requirements, in relation to N fertilizer needs of sugarcane in Pakistan. These experiments were conducted to determine the relationship between irrigation and nitrogen requirement of sugarcane.

MATERIALS AND METHODS

The studies were conducted at the Sugarcane Research Institute, Faisalabad during 1976-77 and 1978-79. The experiments were laid out in an incomplete factorial split plot design. Sugarcane varieties, BL 4 and L. 116 were used. BL. 4 is a broad leaved and medium thick variety, while L. 116 is a narrow leaved and medium thin variety. Five nitrogen levels of 0.56, 112, 168 and 224 kg/ha were used. Half of it was applied at planting and the other half, during closing in June. P_2O_5 and K_2O at 112 kg/ha each, were applied to all the treatments at planting.

The irrigation requirements were based on the pan evaporation recorded daily at the farm. Five irrigation levels were used at coefficients of 0.6, 0.8, 1.0, 1.2 and 1.4 of pan evaporation; 1.0 coinciding with the pan based data, while low coefficients indicated stress conditions and the coefficient above 1.0 an excess in water application. The irrigation was applied at cumulative pan evaporation of around 4"

for each coefficient treatment. This automatically timed the interval of stress and excess moisture levels. The amount of water application per plot for each coefficient of irrigation level was applied through siphon pipes with known calibrated discharge for a given head of water in the water channel. The input levels for water for each coefficient of irrigation were as follows.

	Pan evaporation coefficient.					
	0.6	0.8	1.0	1.2	1.4	
1976–77	97.2	118.6	142.1	163.6	183.4	cm
1978–79	68.4	81.2	112.8	131.3	148.9	cm

Each variety was in the main blocks while irrigation and fetilizer combination treatments were superimposed on the varieties. Of the 25 irrigation x nitrogen combinations, 13 were systematically selected.

The effect of varying levels of irrigation and nitrogen on cane yield were studied. Yield parameters like tillering, cane height and weight, and commercial cane sugar (C. C. S) were recorded during 1976-77 only.

The yield data were statistically analyzed by the method appropriate to split plot design and the means were compared by least significance test. To determine the response of yield to Nitrogen (N) and irrigation (I) multiple regression technique was used where the equations $Y = bo + b_1 I^{3/4} + b_2 I^{3/2} + b_3 N^{3/4} + b_4 N^{3/2} + b_5 N^{3/4} I^{3/4}$ was applied for computing the response surface.

RESULTS AND DISCUSSION

Mean yield for each variety and year are shown in Table 1. Difference in variety yields were significant at 5% level in both years. BL. 4 gave the highest yield. Nitrogen treatments were very highly significant in both years and its variety x treatment interaction in 1978-79.

In order to evaluate individual effects of Nitrogen (N), Irrigation (I) and varieties (V) and to determine various interactions, factorial analysis which was comprised of 3 N (0, 112, 224 kg/ha) and 3 I (0.6, 1.0, 1.4 coeff.) levels was performed. Means of main effects and interaction for these setts are given in Table 2. Nitrogen effects were highly significant in both years. Irrigation effects were highly significant in 1978-79 but not significant in 1976-77. All interactions, except N x I were highly significant in 1978-79, but none were significant in 1976-77 when only the V x N approach significance. Nitrogen had by far the greatest effect. Generally there was a definite pattern of a larger nitrogen response at 1.0 coefficient than at 0.6. However, there was little difference in response between coeffficients of 1.0 and 1.4. In 1978-79, a differential effect of N response between the two varieties was observed. Yields without N were about the same for either variety, but BL. 4 yielded much higher than L. 116 when N was applied.

TABLE 1. Effect of different levels of irrigation and nitrogen fertilizer on the yield of sugarcane varieties BL. 4 and L. 116.

S.No.	Treatments I (Coeff.)	Treatments N (Kg/ha	Cane yield — Tons per hectare 1976—77 BL. 4	L. 116	Mean	1978—79 BL. 4	L. 116	Mean
1.	0.6	224	64.13	45.53	54.83	63.81	46.40	55.11
2.	1.0	224	72.86	62.83	67.85	71.94	61.48	66.71
3.	1.4	224	87.51	59.37	73.44	86.23	62.64	74.48
4.	0.8	168	71.41	46.94	59.18	52.77	45.81	49.29
5.	1.2	168	78.62	66.13	72.37	66.98	66.61	65.80
6.	0.6	112	68.42	50.74	59.58	53.35	41.72	47.54
7.	1.0	112	84.04	62.66	73.35	71.87	55.04	63.46
8.	1.4	112	81.16	57.40	69.28	59.33	60.11	59.72
9.	0.8	56	68.59	47.73	58.16	48.04	47.63	47.86
10.	1.2	56	71.23	55.39	63.56	61.02	53.29	57.15
11.	0.6	0	38.81	37.91	38.36	39.77	37.69	38.73
12.	1.0	0	39.34	31.66	35.50	45.10	41.14	43.12
13.	1.4	0	37.43	28.33	32.88	38.99	35.42	37.20
	Mean		66.46	50.20	58.33	58.25	50.38	54.32
				0.05	*0.01*		*0.05*	*0.01*
L. S. D. for varieties				*10.95*	—		*7.49*	—
Treatments.				*10.38*	*13.85*		*3.14*	*4.26*
V x T				—	—		*6.28*	*8.51*

Data on tillering, cane weight, cane height and CCS% cane recorded in 1976-77 are presented in Table 3. Zero nitrogen at all the irrigation levels reduced tiller formation in cane. Moisture stress due to the lowest irrigation level also had a drastic effect on tillering. The data also showed that different N levels did not improve tillering without adequate application of irrigation water. The drastic effect of low irrigation on tillering had already been reported (Gill[5]). Deficient N reduced cane weights and cane height at all irrigation levels. The C.C.S. data showed that stress or excess of any of the inputs had no effect on the quality of the juice.

Fig. 1 shows the weekly averages of daily evaporation, rainfall, and cumulative supplies of irrigation water for coefficient 1.0. In the early period of crop growth from April to mid-July 1976, the rate of evaporation was high, which accounted for a high cumulative water need of the plant. As the rainy season approached, the transportation rate decreased and the pan evaporation which is indicative of the water needs of the plant, declined from 13.6 mm in June to 3.2 mm in early August. This trend of evaporation determined the time for crop irrigation. Irrigation water had to be applied at short intervals during periods of crop growth when water is highly needed. Of the 142 cm water requirement of the crop, 77% was utilized up to mid-July 50% of which was taken up during the boom period of growth from May to mid-July. For the later growth, the roots were sufficiently developed to utilize the water from lower soil strata. During monsoons, rainy weather reduced the radiation intensity, increased air humidity and minimized the net water loss

TABLE 2. Mean yield main effects and interactions for the 2 varieties x 3 nitrogen x 3 irrigation factorial set

	Cane yield in tons per hectare.							
	1976—77				1978—79			
Irrigation Coeff.								
N kg/ha.	0.6	1.0	1.4	(N x V)	0.6	1.0	1.4	(N x V)
BL. 4 0	38.8	39.3	37.4	38.5	39.8	45.1	39.0	41.3
112	68.4	84.0	81.2	77.9	53.4	71.9	59.3	61.5
224	64.1	72.9	71.4	69.5	63.8	79.4	86.2	74.0
(I x V)	57.1	65.4	63.3	62.0	52.3	63.0	61.5	58.9
L. 116 0	37.9	31.6	28.3	32.6	37.7	41.1	38.1	38.1
112	50.7	62.6	57.4	56.0	41.7	55.0	52.3	52.3
224	45.5	60.4	55.4	55.1	46.4	61.5	56.8	56.8
I x V)	44.7	51.6	43.4	48.2	41.9	52.5	52.7	49.0
Average over varieties.								
0	38.4	35.5	32.9	35.6	38.7	43.1	37.2	39.7
112	59.6	73.3	69.3	67.4	47.5	63.5	59.7	56.9
224	54.8	66.6	65.4	62.3	55.1	66.7	74.4	65.4
(I x V)	50.9	58.5	55.9	55.1	47.1	57.8	57.1	54.0
			0.05	0.01			0.05	0.01
L.S.D. for Varieties.			8.24	—			—	—
Nitrogen			6.18	8.30			2.00	2.76
Irrigation.			—	—			2.00	2.76
N x I			—	—			4.90	6.75
N x V			—	—			4.90	6.75
V x I			—	—			4.00	5.51
V x N x I			—	—			9.80	13.50

TABLE 3. Effect of irrigation and nitrogen fertilizer levels on tillering, cane weight cane height and C.C.S. % cane of sugarcane varieties BL. 4 and L. 116.

S.No.	Treatments		BL. 4				L. 116			
	I Coeff	N ka/ ha	Tillers per plant	Weight per cane	Cane height	C.C.S. % Cane	Tillers per plant	Weight per cane.	Cane height	C.C.S % cane
1.	0.6	224	1.61	0.97	169.5	13.9	2.04	0.53	163.5	14.8
2.	1.0	224	1.83	1.12	187.5	13.8	3.59	0.78	217.5	12.3
3.	1.4	224	1.87	1.18	204.0	14.3	3.23	0.78	200.5	13.7
4.	0.8	168	2.04	1.10	206.5	14.1	3.14	0.67	198.5	13.7
5.	1.2	168	2.02	1.21	248.0	13.6	3.07	0.75	230.5	15.1
6.	0.6	112	1.52	1.03	218.5	14.5	2.57	0.57	207.0	13.8
7.	1.0	112	1.87	0.99	204.0	13.1	3.50	0.70	215.0	13.2
8.	1.4	112	2.05	1.20	215.5	14.1	3.45	0.62	200.5	13.9
9.	0.8	56	1.60	1.04	195.5	14.0	2.71	0.52	163.0	13.8
10.	1.2	56	1.25	0.96	202.0	13.7	2.54	0.66	201.5	13.7
11.	0.6	0	1.11	0.83	168.0	14.0	1.95	0.60	152.5	13.8
12.	1.0	0	1.14	0.79	175.0	14.3	1.87	0.46	148.5	14.5
13.	1.4	0	1.09	0.85	164.0	14.5	1.85	0.45	147.5	14.0

from the transpiring surface. Plant water requirements were met without additional amount of water, thus, irrigation interval was prolonged. The trend was almost the same for both years. However, a prolonged dry period in May and June occurred in 1978-79 due to an absence of sufficient rains, thus pan evaporation rate was high. From July to August, water requirements were considerably reduced due to heavy rains. This is in accordance with the results of Wali and Yusuf1".

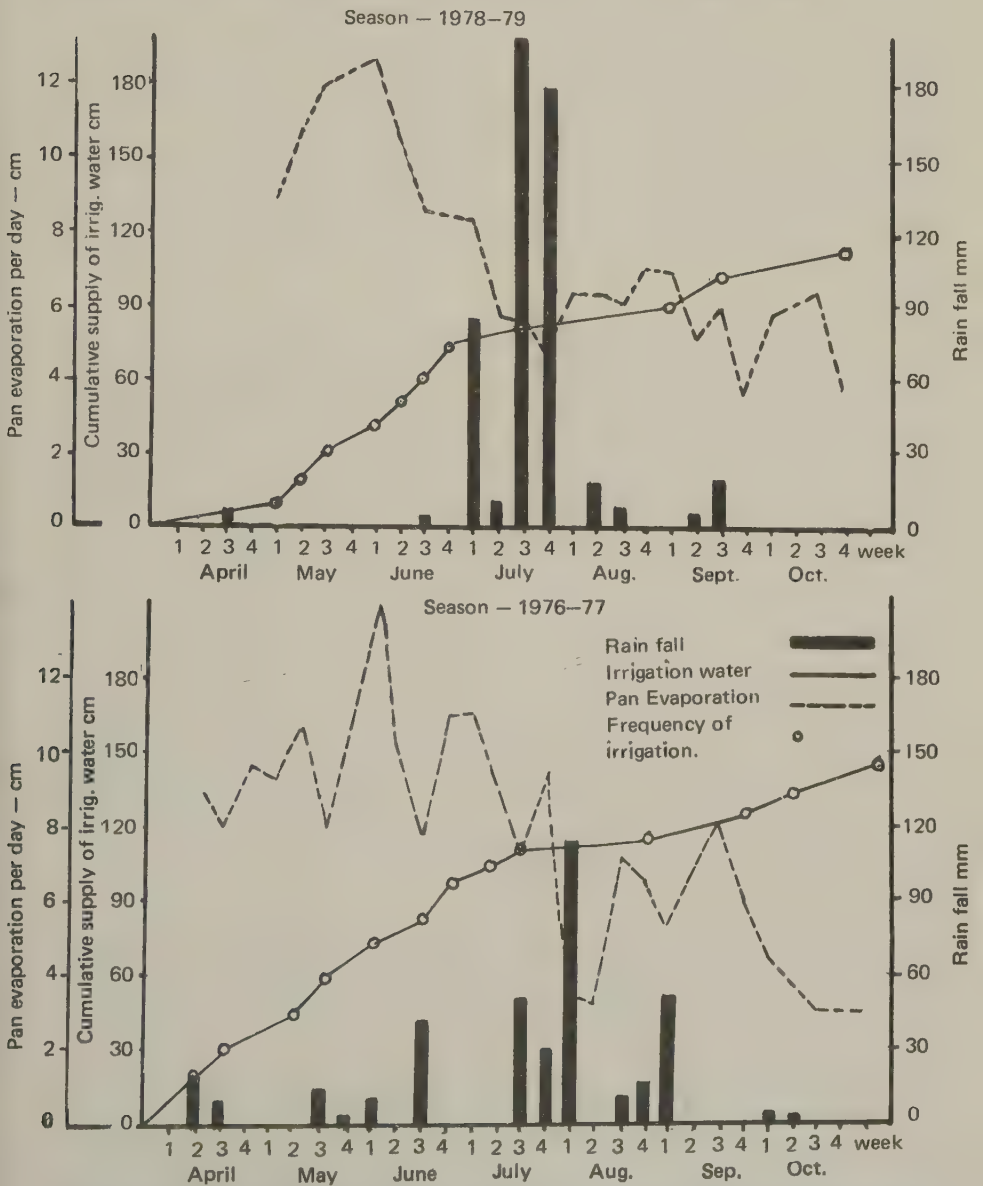
Season — 1978–79
Pan evaporation per day — cm
Cumulative supply of irrig. water cm
Rain fall mm
0 2 4 6 8 10 12
0 30 60 90 120 150 180
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 week
April May June July Aug. Sept. Oct.
Season — 1976–77
Rain fall
Irrigation water
Pan Evaporation
Frequency of irrigation.
Pan evaporation per day — cm
Cumulative supply of irrig. water cm
Rain fall mm
0 2 4 6 8 10 12
0 30 60 90 120 150 180
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 week
April May June July Aug. Sep. Oct.

FIGURE 1. Weekly average of pan evaporation, rainfall and cumulative supply of irrigation water to cane crop.

Apparently, May to mid-July is the most critical period of cane growth for irrigation and when timely rainfalls may give favorable results. In 1976-77, rainfalls were well distributed (Fig. 1) in the early stage of cane growth, thus they marked the effect of stress in the presence of sufficient supplies of N. In 1978-79 significant effects of water stress were noticed. Reduced tillering due to moisture stress and inadequate nitrogen suupply was probably the most important factor limiting cane yield. Fewer tillers contributed to lower cane population at harvest. Moisture strees in the initial stages of plant development badly affected the tillering. Under water stress condition, N application may not affect tillering in the initial stages but it may help promote subsequent growth of cane. Adequate N supplies ensured better early growth to enable the plant to endure stresses during a later period. This is why 112 kg and more of N application in stress conditions gave relatively better yields despite poorer tillering in the initial stages. Nutrient reserves in these treatments compensated yield through increasing cane height and cane weight.

From the yield surfaces estimated by the Multiple Regression technique, yield isoquants were drawn and are shown in Fig 2. It can be seen that with BL. 4, additional water at low N level, there was little effect but yield increased with increasing water at high N levels. There was a major response to N at all irrigation levels, but yield increase at high N levels was unprofitable due to an additional quantity of N. In the combination of inputs applied to BL. 4, 138 cm of water and 90 kg N/ha, yielded 75.0 tons cane per hectare. If the irrigation input was decreased to 120 cm of water, the N input would have to be increased to 135 kg N/ha, to maintain the same yield. If a yield goal of 82.5 tons/ha was desired, the irrigation input would have to be increased to 168 cm of water at 135 kg N/ha fertility rate. The yields were generally lower with L.116 variety. There was a slight tendency for high levels of irrigation to depress yield. There was also a tendency for high N to depress yield at low water levels. It showed that L.116 did not require as much water and N to give optimum yield of cane as that of variety BL.4. To get 52.5 tons cane, maximum N response with 108 cm of water was obtained with about 90 kg N/ha. The highest yield of 80 tons was obtained with 152 cm of water and 115 kg N/ha. The same yield level could be maintained by increasing nitrogen dose. However, this is not very economical for the cane grower. The results thus confirmed previous findings (Singh and Singh[8]. Wali and Yusuf[10]).

The 1978-79 results showed patterns similar to that of 1976-77. Yield decline with high water application could be due to leaching of nitrates (Kemper *et al*[6]). However, yield surface curves gave a choice to select the best combination of N and I for maximum yield response. If the amount of one input is limited the amount of the input can be increased.

From the yield surfaces derived from Multiple Regression, marginal products of produce were calcualted. The marginal product of water /N was the additional ton of cane produced by adding one more ha cm of water/kg N per ha. The calculation showed that as N levels increased, the cane produced per an additional kg of N, decreased. This amount of additional cane produced by one additional kg

Keys to Isoquant number tons/ha

0	:	30.0	4	:	60.0
1	:	37.5	5	:	67.5
2	:	45.0	6	:	75.0
3	:	52.5	7	:	82.5

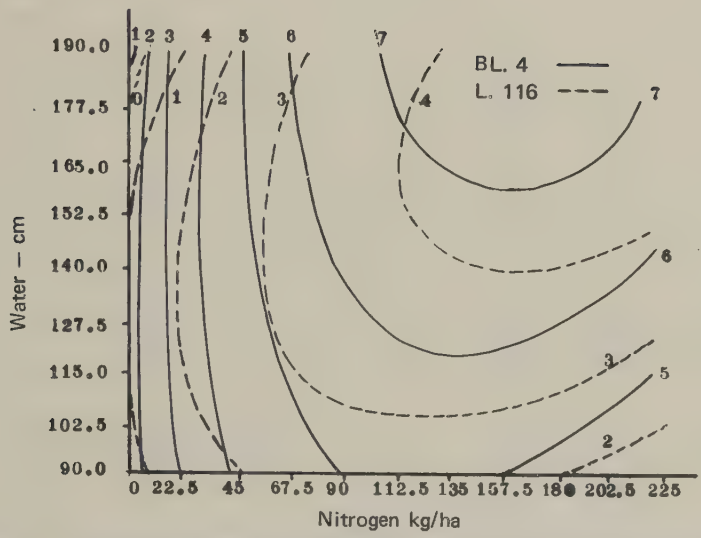

FIGURE 2. Yield isoquants as a function of various input levels of nitrogen and irrigation.

of N, was higher at higher level of water inputs than at lower levels. Conversely, as water increased by one cm the additional cane produced decreased. The increase due to additional water is higher at higher N levels than at low N levels.

Marginal product values were utilized in evaluating the marginal value (marginal product x price of cane) of either water or N. In this case this would be the additional increase generated by one kg N or one ha cm of water. If this increase is greater than the cost of N or water, the input is economically feasible.

Marginal values of water and N for the two varieties in 1976-77 are given in Table 4. Considering the cost of Rs. 3.50/kg N and one irrigation cost of Rs. 5/ha cm of water, the nitrogen fertilizer and irrigation should not be applied unless the value of cane produced by an additional kg of N or ha cm of water is greater than Rs. 3-50 or Rs 5 respectively. It thus defines the range of optimum input combination within which the use of either of the inputs is ecnomically feasible. Black and dotted lines show a range of N and water inputs, respectively. The crop could economically be raised within this range. The Table shows that an addition of 150 kg N/ha to BL. 4 is productive only when 180 cm of water is applied while for L. 116, 180 cm of water is uneconomical at all levels of N. The cost would regulate the optimum level of N or I. If one input is scarce or costly, the other can be substituted to some degree.

A soil-plant-water relationship must be kept in harmony with the nutrient

TABLE 4. Marginal value of water and nitrogen obtained by adding one more ha cm of water and kg N/ha.

N kg/ha		Centimeters water						
		90	105	120	135	150	165	180
				Variety – BL. 4				
25	W	11.28	8.82	6.25	4.10	2.13	0.31	–1.39
	N	37.68	40.29	42.84	45.28	47.66	49.99	52.28
50	W	15.34	12.52	10.02	7.76	5.70	3.80	2.02
	N	22.29	24.50	26.62	28.69	30.70	32.65	34.57
75	W	18.90	15.94	13.33	10.98	8.83	6.85	5.01
	N	12.71	14.70	16.63	18.49	20.30	22.07	23.80
100	W	22.16	19.09	16.37	13.93	11.71	9.66	7.75
	N	5.47	7.33	9.12	10.86	12.54	14.19	15.80
125	W	25.23	22.03	19.22	16.70	14.41	12.29	10.33
	N	–0.46	1.29	2.99	4.63	6.22	7.78	9.30
150	W	28.14	24.84	21.94	19.33	16.97	14.80	12.78
	N	–5.56	–3.89	–2.27	–0.70	–0.82	2.31	3.76
175	W	30.94	27.53	24.54	21.86	19.43	17.20	15.14
	N	–10.08	–8.47	–6.91	–5.40	–3.94	–2.50	–1.10
200	W	33.63	30.13	27.05	24.30	21.81	19.52	17.40
	N	–14.16	–12.60	11.10	–9.64	–8.22	–6.83	5.48
225	W	36.25	32.64	29.48	26.66	24.11	21.77	19.00
	N	–17.90	–16.39	–14.93	–13.51	–12.13	–10.79	–9.47
				Variety – L. 116				
25	W	26.60	18.26	10.82	4.07	–2.13	–7.89	13.27
	N	18.16	21.06	23.85	26.56	29.20	31.77	34.28
50	W	31.07	22.57	14.99	8.12	1.81	–4.04	9.51
	N	10.09	12.52	14.87	17.51	19.37	21.52	23.64
75	W	35.00	26.34	18.64	11.66	5.26	–0.67	–6.21
	N	5.01	7.21	9.33	11.39	13.39	15.34	17.25
100	W	38.60	29.81	21.99	14.92	8.43	2.43	–3.18
	N	1.15	3.20	5.17	7.09	8.95	10.77	12.54
125	W	41.98	33.06	25.14	17.97	11.41	5.34	–0.33
	N	–2.03	–0.09	1.78	3.59	5.35	7.07	8.75
150	W	45.20	36.16	28.13	20.88	14.24	8.10	2.37
	N	–4.77	–2.92	–1.13	0.60	2.98	3.92	5.53
175	W	48.28	39.13	31.00	23.67	16.96	10.75	4.97
	N	–7.20	–5.42	–3.70	–2.04	–0.42	1.16	2.70
200	W	51.26	41.99	33.77	26.36	19.57	13.31	7.47
	N	–9.40	–7.68	–6.02	–4.41	–2.84	–1.31	0.18
225	W	54.14	44.77	36.46	28.96	22.11	15.79	9.89
	N	–11.42	–9.75	–8.14	–6.57	–5.05	–3.57	–2.12

Marginal value = Marginal product x price of cane (Rs. 100/ton).

supplied to the cane plant. Soils receiving adequate fertilizers would produce greater yield per unit of irrigation water than infertile soil. In the present study, 112 kg N/ha, with 112 kg P and K, and irrigation supplies equivalent to pan evaporation, seem to be a fairly good combination for the cane varieties tested. If soil moisture becomes a limiting factor due to shortage of irrigation water, the addition of fertilizer to the crop masks the effect of stress condition at a marginal productivity

level. However, it has to be applied at planting and tillering stage, when plants face minimum moisture stress. Variety BL. 4 responds very well to high dose of N.

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ESTUDIOS SOBRE VARIOS NIVELES DE NITROGENO E IRRIGACION SOBRE EL RENDIMIENTO DE LAS VARIEDADES DE CANA DE AZUCAR BL 4 Y L. 116

Shahab-ud-Din Fasibi, Karim Bakhah Malik y John O. Reuss

RESUMEN

Los experimentos se llevaron a cabo para determinar la relacion entre irrigacion y requierimientos de nitrogeno de las variedades de caña de azucar BL. 4 y L. 116. Se utilizaron cinco niveles de nitrogeno 0, 50, 112, 168 y 224 kg N/ha y cinco niveles de irrigacion a coeficientes de 0.6, 0.8, 1.0, 1.2 y 1.4 de evaporacion de tanque. La cantidad de agua calculada se aplico con pipetas sifon con descarga conocida a determinada carga hidraulica.

Se anotaron datos sobre evaporacion diaria de tanque, ahijamiento, peso de caña, altura de caña y rendimiento de caña. Hasta mediado de Julio se utilizo 77% del agua y 50% se absorbio durante el periodo de maximo crecimiento desde Mayo hasta mediado de Julio. Ceron N bajo todos los niveles de irrigacion redujo el ahijamiento. Los differentes niveles de N no aumentaron el ahijamiento sin la aplicacion adecuada de irrigacion. Aplicaciones mas grandes de N aseguraron mejor crecimiento temprano y compenso el rendimiento al aumentar el peso de la caña y la altura de la caña. Los efectos del N sobre los rendimientos de caña fueron altamente significativos en ambos años. La variedad L. 116 no necesito mucha agua y N para producir optimos rendimientos de caña como fue el caso de la BL. 4. La aplicacion de agua adicional fue poca efectiva a bajos niveles de N, pero el rendimiento aumento al aplicar mas agua con altos niveles de N. No obstante, los incrementos en rendimiento a muy altos niveles de N fueron al costo de nitrogeno adicional. Valores marginales de N e irrigacion fueron calculados que definieron una variacion de combinaciones de entrada. En general 112 kg N con irrigacion equivalente a evaporacion de tanque parece ser una combinacion bastante buena para ambas variedades.

JOHNSONGRASS *(SORGHUM HALEPENSE)* CONTROL AND SUGARCANE TOLERANCE FROM PREEMERGENCE TREATMENTS WITH HEXAZINONE

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ABSTRACT

In Louisiana field experiments, hexazinone [3-cyclohexyl-6-(dimethylamino) -1-methyl-1,3,5-triazine-2,4(IH,3H)-dione] was compared with terbacil (3-tert-butyl-5-chloro-6-methyluracil), a standard herbicide, for the selective preemergence control of weeds in sugarcane (hybrids of the genus *saccharum).* An autumn application of hexazinone at 1.1 kg/ha effectively controlled winter weeds on both silt loam and clay soils. A combination of autumn + spring treatments at 1.1 + 1.1 kg/ha on silt loam or at 2.2 + 2.2 kg/ha on clay was required for effective control of seedling johnsongrass [*Sorghum halepense* (L.) Pers.]. The tolerance of sugarcane to hexazinone, based on yield of cane/ha or sugar/ha, was influenced by herbicide concentration, soil type and cultivar sensitivity. The tolerance categories of sugarcane cultivars were as follows: most tolerant – CP 61-37; intermediate – CP 67-412 and L 62-96; and least tolerant – CP 48-103, NCo 310, and CP 65-357. Hexazinone was much more toxic to sugarcane on silt loam than on either silty clay loam or clay, apparently because of excessive leaching on silt loam. Hexazinone is generally more toxic to sugarcane under Louisiana growing conditions than the widely used herbicide terbacil.

INTRODUCTION

Hexazinone is highly active as a herbicide when applied to plant foliage or when applied to soil and taken up by roots. It is a new herbicide that is now being used for general, nonselective vegetation control. Hexazinone is being extensively evaluated for weed control in sugarcane (McIntyre[1] and Richardson[6]). Some of its chemical properties have been described by Riggleman[7].

The herbicides used for preeemergence control of seedling johnsongrass in Louisiana sugarcane are fenac (2,3,6-trichlorophenyl) acetic acid, metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one] and terbacil. These herbicides are relatively safe for use in sugarcane and provide good control of john-

songrass (Millhollon[2,4] and Stamper[8]). They are applied routinely in autumn on newly planted cane to provide preemergence control of winter weeds, and reapplied in the spring on both plant cane and the ratoons to provide preemergence control of seedling johnsongrass and most other annual weeds.

In this study, hexazinone was compared with standard herbicides for preemergence weed control and crop safety under Louisiana growing conditions.

MATERIALS AND METHODS

A series of field experiments was conducted during 1975-1978 near Houma (H), Chacahoula (C), and Mathews (M), Louisiana. Commercial formulations of hexazinone and other herbicides were applied in water sprays at 374 l/ha to a 91-cm band over the sugarcane drill. Rates are herein expressed as the amount of active ingredient broadcast to a hectare of land. Herbicides were applied either after planting in September or October and during the following March or only in March. The treatments were arranged in randomized complete block designs in plots 5.5 m by 13.7 m. Experiments that were designed to determine the tolerance of sugarcane to hexazinone were harvested for yield in November of each year. Yield of cane/ha and/or sugar/ha was used as a quantitative measure of sugarcane injury.

Some of the chemical and physical characteristics of the soil in these experiments are shown in Table 1. Soil samples obtained from a 15 cm depth were analyzed by a commercial laboratory. Ricaud *et al*[5] have described the variations in the physical and chemical properties that occur within the Commerce, Mhoon, and Sharky groups of soils in the sugarcane area of Louisiana. Throughout this communication, an H, C, or M following the soil texture indicates the location of the experiments.

Annual rainfall during the experiments ranged from 160 to 185 cm which is near the long-term average for the region.

Experiment 1. Hexazinone was evaluated for the control of winter weeds and seedling johnsongrass on silt loam- H (1975), silt loam-C (1977), and clay-M (1975). Sugarcane was planted in October and the beds were packed with a corrugated roller to form shallow furrows for the planting of johnsongrass. Native johnsongrass seed was then broadcasted over the beds at 16 kg/ha and covered to a depth of about 2.5 cm with a smooth roller. Hexazinone, metribuzin, and terbacil were applied at equal rates, ranging from 0.8 to 2.2 kg/ha of the active ingredients. Treatments, replicated 4 times, were applied after planting and reapplied at the same rate the following March before johnsongrass germinated. The surviving johnsongrass plants were counted 60 to 90 days after the spring treatments. Sugarcane was not harvested for yield in this experiment.

Experiment 2. Sugarcane was evaluated for tolerance to relatively high rates of hexazinone at 1.1 to 4.4 kg/ha in autumn and spring. Treatments, replicated 6 times, were applied to cultivar L 62-96 on silt loam-H (1975) and to cultivar CP 61-37 on clay-M (1975).

Experiment 3. The major cultivar CP 65-357, was evaluated for tolerance to possible use-rates of hexazinone at 1.1 to 1.7 kg/ha in autumn and spring. Treatments, replicated 6 times, were applied to clay loam-C (1977) and to silt loam-M (1978). In an adjacent experiment, with 6 replicates, on the same soil and cultivar, the tolerance of sugarcane to a single spring treatment with hexazinone at 1.1 kg/ha was evaluated.

Experiment 4. Six sugarcane cultivars - NCo 310, CP 48-103, L 62-96, CP 67-412, CP 65-357 and CP 61-37 - were evalauted for tolerance to autumn + spring treatments of hexazinone at 1.7 + 1.7 kg/ha and 1;7 + 3.4 kg/ha. The study was conducted during 1977 in a field that contained a silt loam-C soil at one end of the field and a silty clay loam-C soil at the opposite end. The experiment had 3 replicates with 1 replicate each placed on the silt loam, silty clay loam and the intermediate soil. All plots, including the untreated check, were hoed as needed to prevent weed competition.

RESULTS AND DISCUSSION

When hexazinone, metribuzin, and terbacil were applied at equal rates in autumn and spring (Experiment 1), johnsongrass control with hexazinone was about equal to or somewhat better than control with the other herbicides (Table 2). The lowest rates of hexazinone in autumn and spring that gave good johnsongrass control were + 1.1 kg/ha on silt loam-C and 2.2 kg/ha on clay-M. Apparently lower rates may be used in autumn because hexazinone at 0.8 kg/ha on silt loam-H or 1.1 kg/ha on clay-M generally controlled winter weeds as effectively as the standard treatments with metribuzin and terbacil (Table 2). The winter weeds primarily were chickweed *[Stellaria media* (L). Cyrillo], California burclover *(Medicago polymorpha* L. var. *hispida),* Carolina geranium *(Geranium carolinianum* L.), and *henbit (Lamium* amplexicaule L.).

In initial experiments to determine phytotoxicity (Experiment 2), sugarcane was severely injured by certain rates of hexazinone (Table 3). Yield of cane/ha and sugar/ha generally decreased as rates of hexazinone applied in autumn and spring increased from 1.1 to 4.4 kg/ha. When compared to the standard terbacil treatments, hexazinone at rates of 1.1 kg/ha on silt loam-H or 2.2 kg/ha on clay-M, approximate rates needed for weed control, caused moderate reductions in sugar/ha yield. When these rates were doubled however, yield reductions of about 50% were obtained, indicating that the margin of safety with hexazinone is relatively narrow. All rates of hexazinone were more phytotoxic to cultivar L 62-96 on silt loam-H than to cultivar CP 61-37 on clay-M. Sugar content of stalks was not greatly affected by the treatments.

Later tests (Experiment 3) with possible use-rates of hexazinone - 1.1. to 1.7 kg/ha in autumn and spring - again showed that injury to sugarcane was influenced both by the rate of hexazinone and by soil type (Table 4). When compared to the standard terbacil treatment, the hexazinone treatments on clay loam-C reduced yield of sugar/ha by 7 to 16%, depending on rate; in silt loam-M, however, the same treatments reduced yield by 26 to 64%. Hexazinone at 1.1 kg/ha was more toxic

TABLE 1. Chemical and physical characteristics of soil in field experiments.

Series	Texture	Location [1/]	pH	Organic matter (%)	Cation exchange capacity (mcq/100g)	Particle size analysis		
						sand (%)	Silt (%)	Clay (%)
Mhoon	Silt loam	C	6.3	1.4	12.6	24	54	22
Commerce	Silt loam	H	6.6	1.7	13.7	25	54	21
Commerce	Silt loam	M	8.0	0.6	8.5	26	64	10
Mhoon	Silty clay loam	C	6.2	1.6	18.7	17	53	30
Mhoon	Clay loam	C	6.4	1.8	15.8	26	47	27
Sharkey	Clay	M	6.6	4.5	34.5	7	38	55

1/C = Chacahaula, LA; H = Hauma, LA; M = Mathews, LA.

TABLE 2. Control of weeds after preemergence treatment with hexazinone, metribuzin and terbacil (Experiment 1).

Herbicide	Rate/application Autumn (kg/ha)		Spring (kg/ha)	Weed control Winter weeds (%)	Johnsongrass (%)
			1975 experiment (silt loam-H)		
Hexazinone	0.8	+	0.8	97	60
Hexazinone	1.6	+	1.6	100	92
Metribuzin	0.8	+	0.8	98	62
Metribuzin	1.6	+	1.6 [1/]	100	96
Terbacil	0.8	+	0.8	96	57
Terbacil	1.6	+	1.6 [1/]	100	93
			1977 experiment (silt loam C)		
Hexazinone	1.1	+	1.1	100	92
Hexazinone	1.1	+	1.6	100	99
Metribuzin	1.1	+	1.1	100	82
Metribuzin	1.1	+	1.6 [1/]	100	91
Terbacil	1.1	+	1.1	100	87
Terbacil	1.1	+	1.6 [1/]	100	89
			1975 experiment (clay-M)		
Hexazinone	1.1	+	1.1	95	64
Hexazinone	2.2	+	2.2	99	92
Metribuzin	1.1	+	1.1	99	61
Metribuzin	2.2	+	2.2 [1/]	100	85
Terbacil	1.1	+	1.1	97	56
Terbacil	2.2	+	2.2 [1/]	99	87

1/ Standard practice checks (rates may be somewhat lower or higher than those usually used)

TABLE 3. Effect of rate of hexazinone on yield of plant sugarcane (Experiment 2)

				Yield for 2 cultivars 2/					
				L 62-96 on silt loam-H (1975)			CP 61-37 on clay-M (1975)		
	Rate						Sugar/ton		
Herbicide	Autumn (kg/ha)		Spring (kg/ha)	Cane (tons/ha)	Sugar/ton of cane (kg)	Sugar (kg/ha)	Cane (tons/ha)	of cane (kg)	Sugar (kg/ha)
Hexazinone	1.1	+	1.1	40c	122b	4900c	47 bc	111 a	5220 b
Hexazinone	2.2	+	2.2	28 b	114 b	3150 b	42 b	115 a	4870 b
Hexazinone	4.4	+	4.4	11 a	99 a	1120 a	23 a	111 a	2590 a
Terbical	1.8	+	1.8 1/	57 d	115 b	6590 d	53 c	115 a	6040 c

1/ Standard practice check

2/ Yields within a column followed by the same letter are not significantly different at the 5% of probability as determined by the Duncan's multiple range test.

TABLE 4. Effect of possible use-rates of hexazinone on yield of CP 65-357 sugarcane (Experiment 3)

Herbicide	Rate Autumn (kg/ha)		Rate Spring (kg/ha)	Yield on 2 soils 2/ Silt loam-M (1978) Cane (tons/ha)	Sugar/ton of cane (kg)	Sugar (kg/ha)	Clay loam-C (1977) Cane (tons/ha)	Sugar/ton of cane (kg)	Sugar (kg/ha)
Hexazinone	1.1	+	1.1	56 c	120 ab	6700 c	80 a	101 a	8020 ab
Hexazinone	1.1	+	1.7	37 b	113 a	4190 b	73 a	98 a	7200 a
Hexazinone	1.1	+	1.7	29 a	112 a	3240 a	72 a	100 a	7250 a
Terbicil	1.7	+	1.7 1/	71 d	128 b	9100 d	80 a	108 b	8620 b

1/ Standard practice check

2/ Yield within a column followed by the same letter are not significantly different at the 5% level of probability as determined by the Duncan's multiple range test.

TABLE 5. Yield of CP 65-357 plant sugarcane on silt loam-M as affected by single and dual applications of hexazinone and terbacil (Experiment 3).

Herbicide	Rate			Yield		
	Autumn (kg/ha)		Spring (kg/ha)	Cane (tons/ha)	Sugar/ton of cane (kg)	Sugar (kg/ha)
				Test A 1/		
Hexazinone	0.0	+	1.1	64 a	131 a	8390 a
Terbacil	0.0	+	1.7 2/	72.b	138 a	9960 b
				Test B 1/		
Hexazinone	1.1	+	1.1	56 a	120 a	6700 a
Terbacil	1.7	3	1.7 2/	71 b	128 a	9100 b

1/ Test A and B were on adjacent rows but in separate randomized complete block experiments. Yields within a column in each test followed by the same letter are not significantly different at the 5% level of probability as determined by the Duncan's multiple range test.

2/ Standard practice check.

TABLE 6. Influence of pre-emergece treatments with hexazinone on yield of 6 sugarcane cultivars (Experiment 4)

Rate of hexazinone			Cultivar					
Autumn (kg/ha)		Spring (kg/ha)	NCo 310	CP 48-103	L 62-69	CP 67-412	CP 65-357	cp 61-37
					Yield of cane (tons/ha) 2/			
0.0	+	0.0 1/	90 c	59 c	60 c	61 c	55 b	88 c
1.7	+	1.7	49 b	34 b	43 b	44 b	27 a	75 b
1.7	+	3.4	24 a	16 a	23 a	30 a	15 a	59 a
					Yield of cane as % of untreated check			
1.7	+	1.7	55	58	71	73	49	85
1.7	+	3.4	27	26	38	50	28	68
Mean			41	42	55	61	38	77

1/ Untreated, hand-weeded check.

2/ Yields within a column followed by the same letter are not significantly different at the 5% level of probability determined by the Duncan's multiple range test.

TABLE 7. Influence of soil variation in the field on response of sugarcane cultivars to hexazinone (Experiment 4)

Rate of hexazinone				Yield of cane (tons/ha as % of untreated check						
Autumn (kg/ha)		Spring (kg/ha)	Texture of soil	NCo 310 (%)	CP 48-103 (%)	L 62-96 (%)	CP 67-412 (%)	CP 65-357 (%)	CP 61-37 (%)	Mean (%)
1.7	+	1.7	silt loam-C	43	41	43	57	34	64	47
1.7	+	1.7	silty clay loam-C	66	79	100	82	72	100	83
1.7	+	3.4	silt loam-C	11	12	34	25	16	54	25
1 7	+	3.4	silty clay loam-C	42	40	52	63	45	81	54

sugarcane on the silt loam-M soils when applied both in autumn and spring than when applied only in spring (Table 5). The sugar content of stalks was only slightly reduced by hexazinone treatments (Tables 4 and 5).

The lowest rate of hexazinone used in Experiment 2 and 3 (1.1 kg/ha in autumn and spring) effectively controlled most summer annual grass and broadleaved weeds including browntop panicum *(Panicum fasiculatum* Swartsz), junglerice [*Echinochloa colonum* (L). Link], and large crabgrass [*Digitaria* sanguinalis (L.) Scop.]. Browntop panicum has spread widely in Louisiana sugarcane because it is not controlled by terbacil (Millhollon[3]).

Sugarcane cultivars in Experiments 4 were differentially tolerant to hexazinone applied in autumn and spring at either 1.7 + 1.7 kg/ha or 1.7 + 3.4 kg/ha (Table 6). The mean yields of cane/ha for the two treatments, calculated as a % of the untreated check, were as follows: CP 61-37:77% (most tolerant); CP 67-412: 61% and L 62-06:55% (intermediate); and CP 48-103:42%, NCo 310:41% and CP 65-357:38% (least tolerant). The magnitude of the yield reductions caused by hexazinone was influenced by the soil variation in the field which ranged from a silt loam-C to a silty clay loam-C (Table 7). Hexazinone was about twice as toxic on the silt loam as on the silty clay loam. The primary difference between these two soils was the higher clay content in the silty clay loam (Table 1).

Information developed in this study shows that the tolerance of sugarcane to hexazinone is influenced by herbicide concentration, soil type, and cultivar sensitivity. Hexazinone is characterized as being moderately adsorbed by soil colloids and is relatively mobile in soil (Riggleman[7]). Sugarcane injury probably was caused by the leaching of the herbicide into the sugarcane root zone. The leaching of many herbicides decreases as the adsoprtive capacity - clay, organic matter content, and cation exchange capacity of soils increases. In this study, the clay content of soils was particularly important in preventing excessive injury from hexazinone.

These results indicate that hexazinone can be used for weed control in Louisiana with reasonable crop safety if treatment is limited to silty clay loam, clay loam or clay soils. Clearly, hexazinone is inherently more phytotoxic to sugarcane under Louisiana growing conditions than is the widely used herbicide terbacil.

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CONTROL DE YERBA JOHNSON Y TOLERANCIA DE CAÑA DE AZUCAR CON TRATAMIENTOS PRE-EMERGENTES DE HEXAZINONE 1/

R. W. Millhollon

RESUMEN

En experimentos de campo llevados a cabo en Louisiana, hexazinone [3-ciclohexil-6-(dimetilamino)-1-metil-1,3,5-triazina-2,4 (1H , 3H)-dione] fue comparado con terbacil (3-tert-butil-5cloro-6-metiluracil), un herbicida standard, para el control selectivo de malezas en preemergencia en caña de azucar (hibridos del genero *Saccharum).* Una aplicacion en el otoño de hexazinone, a 1.1 kg/ha, controlo efectivamente las malezas de invierno en suelos tanto franco limosos como arcillosos. Para controlar efectivamente las plantulas de yerba Johnson [*Sorghum halepense* (L) Pers.] fue necesario una combinacion de tratamientos de otoño + primavera a 1.1 + 1.1 kg/ha en suelos franco limosos o a 2.2 +2.2 kg/ha en suelos arcillosos. La tolerancia de caña de azucar hacia hexazinone, basado en rendimientos de caña/ha o azucar/ha, fue afectada por la concentracion del herbicida, tipo de suelo y susceptibilidad de los cultivares. Las categorias de tolerancia de los cultivares de caña de azucar fueron las siguientes: mas tolerante - CP 61-37; intermedia - CP 67-412 y L 62-96; y menos tolerante - CP 48-103 NCo 310 y CP 65-357. Hexazinone fue mucho mas toxico para la caña

1/ *Contribucion de AR, SEA, USDA en cooperacion con la Estacion Experimental Agricola de Louidiana.*

de azucar en suelo franco limoso que en suelos franco arcilloso limosos o arcillosos, aparentemente debido al exceso de lixiviacion en suelo franco limoso. Generalmente hexazinone es mas toxico para la caña de azucar, bajo las condiciones de cultivo de Louisiana, que el herbicida terbacil que se utiliza extensivamente.

THE CONTROL OF *CYPERUS ROTUNDUS* IN SUGAR CANE FIELDS AND IN FALLOW LAND

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ABSTRACT

Cyperus rotundus is one of the most troublesome weeds growing in agricultural lands of Mauritius. Efforts are constantly being made to eradicate it by testing a number of herbicidal treatments in ratoon canes and in fallow land.

In ratoon canes, the best results have been obtained with post-emergence spraying of Velpar K_4 (hexazinone + diuron) used either alone or in mixtures with Actril-DS (ioxynil-2,4-D) or 2,4-D amine salt. On *C. rotundus* subsp. *tuberosus*, only one application was needed to get very satisfactory control whereas on *rotundus*, two applications were necessary.

In fallow land exceptional control was obtained with glyphosate. Very satisfactory result was also obtained from the application of hexazinone.

INTRODUCTION

Cyperus rotundus is known to be one of the world's worst weeds. It is one of the most troublesome weeds in Mauritius. It occurs very commonly in all climatic regions and in different soil types. It is highly competitive and often causes complete failure of crops, particularly small-sized annual crops like carrots. In dry regions, perennial crops like sugarcane are severely affected (McIntyre[1]).

In Mauritius there are two subspecies of *Cyperus rotundus* which can be easily differentiated by the following characters:

1. *Cyperus rotundus* L. subsp. *rotundus* Hooper, bears a reddish, dark-brown inflorescence; it is commonly found in all climatic regions and soil types.

2. *Cyperus rotundus* L. subsp. *tuberosus* (Rottb.) Kük bears a golden brown or straw colored inflorescence. When growing under the same conditions, this subspecies is usually larger than the former.

It must be noted that under local conditions, *C. rotundus* does not seem to reproduce by seeds. Vegetative propagation by bulbs is very efficient with a tenfold increase in the population of the weed occurring in just a few months. Vaughan and McIntyre[2] have described various aspects relating to the weed in their leaflet.

MATERIALS AND METHODS

Two trials were made in ratoon canes and another two in fallow land in order to determine which herbicidal treatment would achieve the most satisfactory control of *C. rotundus* under different conditions. In all the trials, the statistical design used was a randomized block with three replicates for each treatment. In canes, the plot size was of 4 rows, 6.5 meters long; in fallow land, plot size was 50 square meters in one of the trials and 250 square meters in the other. The amount of water used to apply the herbicides was 650 liters per hectare and spraying was done by hand-pump knapsack sprayers.

Trials in ratoon canes

In the first trial (Trial 1) both subspecies of *C. rotundus* were present but subsp. *rotundus* occurred only occasionally. Six post-emergence treatments were compared to an untreated control, *C. rotundus* subsp. *tuberosus* had already flowered abundantly and its percentage ground cover was estimated throughout the experiment, just before spraying, six weeks after the previous harvest. The experiment was visited regularly and a final assessment was made ten weeks after spraying. In all the other trials, only *C. rotundus* subsp. *rotundus* occurred. Consequently, no mention of the subspecies will henceforth be made.

In the second trial (Trial II) eight herbicidal treatments were compared to an untreated control. Four of these treatments were Eradicane 6E (EPTC + R25788). Rates of 3 and 6 kg. a.e./ha. were tested. Each was either sprayed and then manually incorporated with a hoe, or sprayed without incorporation. The other treatments were also sprayed in post-emergence of the weed which had just started to flower. Eight weeks later, all the treatments, except Eradicane 6E were re-sprayed in order to further improve weed control.

Trials in fallow land

Seven post-emergence herbicidal treatments were tested in one of the trials (Trial III) where the plot size was 250 square meters. Eradicane 6E was incorporated into the soil by means of a tractor-mounted rotary hoe, immediately after spraying. The rotary hoe was also used in half the surface area of the control plots in order to determine the level of control of Eradicane 6E and to observe whether this chemical can retard or suppress germination of *C. rotundus*, as it is usually claimed. At the time of spraying the weed had flowered abundantly.

Four post-emergence and one pre-emergence treatments were compared to an untreated control in the fourth trial (Trial IV). Three plots were hand-

weeded prior to spraying of the pre-emergence treatment. The percentage ground cover of *C. rotundus* was estimated before spraying and 20 weeks later.

RESULTS AND DISCUSSION

Trial I

The treatments and the estimated percentage ground cover of *C. rotundus* before spraying, and ten weeks later, are given in Table 1.

It can be observed that very satisfactory control of the weed was obtained with Velpar K4 used alone and in mixtures with Actril-DS (ioxynil + 2,4-D) or 2,4-D amine salt. (Velpar K4 is a mixture of hexazinone and diuron in an approximate ratio of 1:4 respectively).

Good weed control was also obtained with the mixture diuron + Actril-DS + sodium chlorate. Using Actril-DS or 2,4-D amine salt alone gave a fair control of the weed, with the former giving somewhat better results than the latter.

It must be pointed out that 2 to 3 weeks after spraying, the weed leaves in all the treated plots have completely dessicated. Regrowth, however, started two weeks later and reached different infestation figures showing which treatment is the best.

Trial II

The percentage cover of *C. rotundus* was estimated prior to spraying and twenty weeks later in all the treatments. These details are given in Table 2.

Eight weeks after the spraying, it was evident that practically no weed control had been obtained with Eradicane 6E irrespective of rates of incorporation. Appreciable regrowth had occurred in the other treatments and it was decided to re-spray them. Twelve weeks later, a final assessment was made. A very good control of *C. rotundus* with more than 90% kill, was obtained with Velpar K4 alone and in mixtures with Actril-DS or 2,4-D amine salt. Fair control was obtained with Actril-DS. The three Velpar K4 treatments were practically free from weeds whereas the plots treated with Actril-DS were being invaded by many grasses, particularly *Digitaria adscendens* and *Setaria pallide-fusca* and certain broad-leaved weeds like *Agetatum conyzoides* and *Cyperaceae* like *Kyllinga monocephala.*

Trials III

Table 3 gives the treatments compared in this trial and their respective estimated percentage cover of *C. rotundus* prior to spraying and twelve weeks later.

Spectacular weed control was obtained with Roundup (glyphosate) at 1 kg. a.e./ha. The two mixtures of Velpar K4 with Actril-DS were also satisfactory

TABLE 1. Control of *C. rotundus* subsp. *tuberosus* by post-emergence herbicidal treatments in ratoon canes – Trial 1

Herbicides	Dosage	Mean % cover of *C. rotundus*		% kill
	kg a.e. or a.i./ha.	before spraying	10 weeks later	
Velpar K4	3.0	51.6	6.7	87.0
Velpar K4 + Actril-DS	3.0 + 1.2	56.7	3.3	94.0
Velpar K4 + 2,4-D amine salt	3.0 + 2.0	64.2	7.3	88.6
Diuron + Actril-DS + sodium chlorate	2.0 + 1.2 + 1.0	36.7	11.0	70.0
Actril-DS	1.2	35.3	16.2	54.1
2,4-D amine salt	2.0	48.3	26.7	44.7
Untreated control	—	49.5	50.0	—

TABLE 2. Effect of various post-emergence herbicidal treatments on *C. rotundus* growing in ratoon canes – Trial II

Herbicides	Dosage	Mean % cover of *C. rotundus*		% kill
	kg a.i. or a.e./ha.	before spraying	20 weeks later	
Velpar K4	3.0	46.7	2.3	95.0
Velpar K4 + Actril-DS	3.0 + 1.2	40.0	2.0	95.0
Velpar K4 + 2,4-D amine salt	3.0 + 2.0	46.7	2.3	95.0
Eradicane 6E +	3.0	41.7	43.0	nil
Eradicane 6E +	6.0	43.3	45.3	nil
Eradicane 6E ++	3.0	56.7	56.3	nil
Eradicane 6E ++	6.0	36.7	39.3	nil
Actril-DS	1.2	46.7	25.7	45.0
Untreated control	—	50.0	53.0	—

\+ *not incorporated*
++ *incorporated*

TABLE 3. Effect of post-emergence herbicidal treatments on *C. rotundus* in fallow land – Trial III

Herbicides	Dosage	Mean % cover of *C. rotundus*		% kill
	kg a.i. or a.e./ha.	before spraying	12 weeks later	
Roundup	1.0	67.3	1.0	98.5
Frenock	4.0	52.7	26.0	50.7
Frenock + 2,4-D amine salt	2.0 + 2.0	70.0	37.3	46.7
Eradicane 6E +	3.0	57.7	65.0	nil
Eradicane 6E +	6.0	62.7	67.3	nil
Velpar K4 + Actril-DS	2.5 + 1.2	70.0	23.1	67.0
Velpar K4 + Actril-DS	5.0 + 1.2	52.7	13.2	75.0
Untreated control +	–	55.0	70.0	–
Untreated control	–	65.0	70.0	–

+ *mechanically incorporated with a rotary hoe*

TABLE 4. Effect of pre- and post-emergence treatments on *C. rotundus* in fallow land – Trial IV

Herbicides	Dosage	Mean % cover of *C. rotundus*		% kill
	kg a.i. or a.e./ha.	before spraying	20 weeks later	
Roundup	1.0	70.0	21.7	69.0
Velpar	1.0	71.7	23.7	67.0
Velpar	2.0	73.3	21.3	70.9
Velpar	4.0	66.7	15.0	77.5
Destun +	4.0		75.0	nil
Untreated control		65.0		

+ *applied in pre-emergence of the weed*

whereas fair weed control was obtained with Frenock (tetrapion) used alone or mixed with 2,4-D amine salt. No reduction in the population of *C. rotundus* was observed with Eradicane 6E but the germination of weed was retarded. Emergence of the weed was delayed to about 3 weeks after spraying, whereas in the control plots it had started after 10 days. In all the plots where rotary hoe had been used, the percentage weed cover had increased probably due to the dissemination of the bulbs in areas not originally infested. In fact, in the control plots, the weed cover had increased by 15%.

Trial IV

The pre and post-emergence treatments and their respective percentage weed cover are given in Table 4. It must be noted that in this trial, Velpar was used as such, not as Velpar K4 which is already mixed with diuron.

Very good weed control was obtained in all the post-emergence treatments. The pre-emergence treatment Destun (perfluidone) was totally ineffective. There was little difference between the results obtained from the three rates of Velpar. However, the higher the rate, the quicker the kill. The weed leaves in the Velpar plots were completely desiccated after three weeks but regrowth started approximately six weeks after spraying. However, many of these re-growths showed strong chlorosis and subsequently died. The results indicated that increase in efficacy of Velpar was very slightly influenced by increases in rates; consequently it is not necessary to use rates higher than 1 kg. a.i./ha. In fact the amount of Velpar in Velpar K4 tested in the other trials varied between 0.7 and 1.4 kg a.e./ha.

CONCLUSION

In fallow land, *C. rotundus* can be completely controlled with Roundup at 1 kg a.e./ha. Spot spraying of the regrowth should be done with the same herbicide at the same rate. This herbicide is rapidly decomposed upon contact with the soil so that any crop can be planted afterwards without any risks of phytotoxicity. Velpar or Velpar K4 can also be used and they have the advantage of controlling other weeds in pre-emergence as well as in post-emergence. However, with a fairly long residual effect, these chemicals can cause phytotoxity to susceptible crops.

In ratoon canes, *C. rotundus* subsp. *tuberosus* is efficaciously controlled by Velpar K4 alone and in mixtures with Actril-DS and 2,4-D amine salt. For the subsp. *rotundus* however, two applications are needed to get equivalent results. One application of Velpar K4 at 3 kg a.i./ha. is safe in ratoon canes, but a second application could prove detrimental to cane growth. Consequently, when tw· herbicide applications are necessary, it is advisable to have one with Velpar K4 + Actril-DS and another with Actril-DS alone.

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CONTROL DE CYPERUS ROTUNDUS EN CAÑAVERALES Y TERRENO BARBECHO

G. McIntyre, C. Barbe, J. Pitchen and M. Yerriah

RESUMEN

Cyperus rotundus as una de las malezas mas dificultosas que crece en terrenos agricolas en Mauricio. Continuamente se realizan esfuerzos para erradicarla haciendo pruebas con numerosos herbicidas en cañas de retoño y en terreno barbecho.

En retoños, se han obtenido los mejores resultados con aspersiones post-emergentes de Velpar K4, utilizado solo o mezclas con Actril-DS o 2,4-D sal amina. Solamente era necesaria hacer una aplicacion para obtener resultados muy satisfactorios para controlar *C. rotunda* sub sp. *tuberosus* mientras que eran necesarias dos aplicaciones en el caso de la sub sp. *rotundus.*

En terreno barbecho se obtuvo un control excepcional con Roundup aunque Velpar tambien fue muy satisfactorio.

JOHNSONGRASS COMPETITION AND CONTROL IN SUCCESSION–PLANTED SUGARCANE

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ABSTRACT

Sugarcane (hybrids of the genus *Saccharum*) was planted directly following a third-ratoon crop of sugarcane heavily infested with johnsongrass [*Sorghum halepense* (L.) Pers.] and without the year of fallow standard in Louisiana. The johnsongrass infestation in the new crop (with no herbicide treatment) was extremely high, about 10 rhizome plants and 100 seedlings per m^2 during the first year. Pre-emergence treatments with terbacil (3-*tert*-butyl-5-chloro-6-methyl-uracil), fenac [(2,3,6-trichloropheny) acetic acid] or picloram (4–amino-3,5,6-trichloropicolinic acid or a combination treatment with TCA (trichloroacetic acid) and fenac were applied in the autumn after the succession planting and again each year during the 3-year crop cycle. These treatments effectively controlled johnsongrass seedlings, but only picloram effectively suppressed the development of rhizome plants. The control of rhizome plants improved considerably when the pre-emergence plots also were treated post-emergence each spring with MSMA (monosodium methanearsonate) or dalapon (2,2-dichloropropionic acid); control was better by MSMA than by dalapon. Average yields of sugar/ha for the three crops, as percentage of the handweeded check, were 49% for pre-emergence treatments alone, 76% for pre-emergence treatments plus dalapon, and 92% for the pre-emergence treatments plus MSMA. The study showed that under Louisiana conditions johnsongrass competition in succession-planted sugarcane can be reduced to acceptable levels with effective combinations of pre-emergence and post-emergence herbicides.

INTRODUCTION

In Louisiana, a sugarcane crop cycle routinely last 3 years, and the land is fallow-plowed for a growing season before replanting. Fallow plowing successfully reduces the population of johnsongrass rhizomes and seed in soil and consequently, reduces johnsongrass competition in the new crop. When johnsongrass is not a major problem, some growers eliminate fallow plowing and plant a new crop immediately after the old one is plowed out, thereby following a system of continuous cropping. In Louisiana, the new crop must be planted

within a month after harvest begins in October to avoid possible freeze damage to seed cane. Consequently, favorable weather is necessary for the intensive cultivation that is needed for seedbed preparation.

In recent years, herbicide treatments have been developed that provide effective pre and post-emergence control of johnsongrass (Millhollon[3,4], Stamper[7]); with these treatments succession planting may be possible even in fields heavily infested with johnsongrass. The feasibility of that practice has been studied.

MATERIALS AND METHODS

This study was a 3-year field experiment on a silt loam soil near Mathews, Louisiana. On October 23, 1965, a third-ratoon crop of sugarcane heavily infested with johnsongrass was destroyed by reversing the rows twice with a moldboard cane plow. A seedbed was prepared by tilling the new beds with a power-driven rotary tiller. This tiller chopped the johnsongrass rhizomes into 1 and 2 node pieces about 5 to 8 cm long and distributed them in the top 33 cm of the bed. Stalks of sugarcane cultivar CP 52-68 were then planted in the beds on November 2, 1965.

The treatments with herbicides were pre-emergence by post-emergence factorials arranged in a split-plot design with 4 replicates. Subplots (5.4 m x 15.2 m) were pre-emergence herbicide treatments and main plots were post-emergence herbicide treatments. Pre-emergence treatments were fenac (5 kg/ha), terbacil (1.8 kg/ha), a fenac-TCA treatment, and a handweeded check. Fenac and terbacil were applied after planting and re-applied in March during each of the following 3 years. For the fenac-TCA treatment, a mixture of TCA (11.2 kg/ha) and silvex [2-(2,4,5-trichlorophenoxy) propionic acid] (2.8 kg/ha), was applied after planting, fenac (7.6 kg/ha) was applied the following March, and a mixture of TCA (19.7 kg/ha) and silvex (3.4 kg/ha) was applied each spring in the ratoons. Post-emergence herbicide treatments were dalapon (5 kg/ha) and MSMA (4.5 kg/ha). They were applied over the top of sugarcane and johnsongrass, to the plant crop in mid-May and to the ratoon crops in mid-April, when rhizome johnsongrass was 30 to 36 cm tall. All herbicides were applied in either a 61 or 91 cm band width in the sugarcane drill; herbicides were diluted with water at 375 and 563 l/ha for the pre and post-emergence treatments, respectively. A 0.5% v/v non-ionic surfactant was mixed with the post-emergence herbicides.

All plots were cultivated as needed to control weeds on the sides of beds. In July of each year, when cane height prevented further cultivation, johnsongrass infestations in the water furrows were controlled with a directed application of MSMA (3.9 kg/ha) or dalapon (6.7 kg/ha).

Johnsongrass infestations were estimated by counting seedlings and rhizome stools in either small quadrats or entire plots. Counts were made in mid-June in plant cane, and in mid-May in the ratoon crops, about 1 month after post-emergence herbicides were applied. The non-treated, weed-free checks were

kept free of weeds throughout each year by hand-weeding.

Each year the harvestable stalks/plot were counted in September, and plots were harvested in early November to obtain cane yields. Sucrose content of stalks was obtained by extracting the juice from 15-stalks/plot in a sample mill and analyzing the juice by polarimetry. Sugar/ha were calculated from cane wts and % sucrose. The number of stalks/ha and yield of sugar/ha were used as quantitative measures of the efficiency of herbicide treatments in preventing johnsongrass competition and in allowing relatively normal growth of sugarcane.

Samples of sugarcane stalks from MSMA-treated plots were analyzed for arsenic residues. A 6-stalk sample of sugarcane, randomly selected from 2 replicates and topped at a point just above the last mature node, was crushed 3 consecutive times in a sugarcane sample mill to extract the juice. Sugarcane juice and bagasse were then analyzed quantitatively for elemental arsenic according to method 24.014 of the AOAC (Association of Official Agricultural Chemists[1]). The lowest concentration of arsenic that could be accurately detected by the analytical method was 0.05 ppm; therefore, lower concentrations are also listed as 0.05 ppm.

RESULTS AND DISCUSSION

Following succession planting, the initial infestation of johnsongrass in plant cane, as shown by the non-treated check, was extremely high-about 10 rhizome stools and 117 seedlings per m^2 (Table 1).

Fenac, terbacil and picloram, applied pre-emergence without supplementary post-emergence treatment, effectively controlled seedlings in the plant crop and apparently in the ratoons as well (Table 1). Picloram and fenac also suppressed development of rhizome plants in plant cane, but terbacil did not. In the ratoon crops, only picloram continued to suppress the development of rhizome plants. The rhizome plants in plant cane grew from the short pieces of rhizomes that remained after treatment with the rotary tiller during the previous year. These plants developed new rhizome systems very slowly and therefore were not well established in the plant crop but were much better established in the ratoon crops. Short rhizome pieces are particularly sensitive to herbicides that are toxic to developing roots (Millhollon[6]). Both picloram and fenac are mobile in soil and toxic to roots, but my observations indicate that picloram is the more toxic of the two.

Post-emergence treatments with MSMA or dalapon effectively reduced the number of rhizome plants that survived the pre-emergence treatments (Table 1). MSMA controlled johnsongrass more effectively than dalapon, particularly in the ratoon crops. These or similar post-emergence treatments would be essential for the control of the high population of rhizome plants that would survive the standard fenac, terbacil, or fenac-TCA treatments.

TABLE 1. Estimated johnsongrass infestation in succession-planted sugarcane following annual treatments with herbicides during a 3-year crop cycle.

Pre-emergence herbicides and rate of (kg/ha)/application	Number of rhizome stools and seedlings in a band 38 cm or 43 cm wide over sugarcane					
	Plant cane		First ratoon		Second ratoon	
	Rhizome (No./m²)	Seedling (No./m²)	Rhizome (No./m²)	Seedling (No./m²)	Rhizome (No./m²)	Seedling (No./m²)
None (Weedy check)	10.8	117.3	>75.0[2]	>100.0[2]	>90.0[2]	>100.0[2]
	None post-emergence					
Fenac-5.0	1.9	0.3	48.8	<5.0	63.8	<5.0
Terbacil-1.8	10.7	0.2	73.6	<5.0	86.1	<5.0
Picloram-1.7	0.2	0.0	1.7	0.2	6.2	0.3
Penac-TCA[1]	3.2	1.5	63.7	<5.0	40.7	<5.0
	Dalapon (5.0 kg/ha) post-emergence					
Fenac-5.0	0.5	0.1	3.9	0.1	13.1	0.3
Terbacil-1.8	1.1	0.1	3.4	0.2	17.8	1.0
Picloram-1.7	0.1	0.0	1.6	0.1	3.8	0.2
Fenac-TCA[1]	1.2	0.3	3.1	0.9	8.7	8.5
	MSMA (4.5 kg/ha) post-emergence					
Fenac-5.0	0.1	0.1	0.4	0.1	0.8	0.6
Terbacil-1.8	0.2	0.1	0.6	0.3	1.9	1.8
Picloram-1.7	0.0	0.0	0.3	0.2	0.2	0.2
Fenac-TCA[1]	0.1	0.2	0.2	0.8	1.6	3.4

1<*Treatment consisted of a mixture of TCA (11.2 kg/ha) + silvex (2.8 kg/ha) applied after planting; fenac (7.6 kg/ha) applied the following spring, and a mixture of TCA (19.7 kg/ha) + silvex (3.4 kg/ha) applied to the ratoons each spring.*

2>*Indicate that because of the heavy rhizome johnsongrass population, the number of plants were estimated.*

Yields for the nontreated, hand-weeded plots are shown in Table 2, and yields for herbicide treatments calculated as a percent of these weed-free plots are shown in Table 3. Two general observations may be made about yields during the experiment: (1) plant-cane stand and yield were about 10% less than expected, probably because of an extended drought that followed planting, and (2) the stalk population and yield in the second ratoon declined by about 35% from the yield in the first ratoon crop (Table 2).

The number of stalks and yield of sugar/ha produced in the herbicide-treated plots in each crop were influenced primarily by the level of johnsongrass control (Tables 1 and 3). In plots with inadequate control, johnsongrass competition reduced the number of harvestable sugarcane stalks, which in turn contributed to reduction in the yield of sugar/ha (Table 3). Individual stalk weight and sugar content of stalks, the other components of sugar/ha yield, were not greatly affected by the treatments (data not presented).

When fenac, terbacil, and fenac-TCA were used without a post-emergence

treatment, annual sugar yields declined rapidly and progressively from plant

TABLE 2. Yield of succession-planted sugarcane maintained weed-free by hand-weeding during a 3-year crop cycle.

Sugarcane crop	Yield at harvest			
	Plant population (stalks/ha) (x 1000)	Sugarcane (ton/ha)	Sugar in sugarcane (kg/ton)	Sugar (kg/ha)
Plant cane	58.8	59	97	5660
First ratoon	72.3	66	102	6730
Second ratoon	51.3	42	103	4380

cane through the second ratoon, indicating that johnsongrass competition was severe. Sugar yields, as a percent of the weed-free check, ranged from 66% to 80% in plant cane and from 14% to 19% in the second ratoon. When these pre-emergence-treated plots also received dalapon as a post-emergence treatment, yields relative to the hand-weeded check declined less rapidly, but were still lower in the second ratoon than in the previous crops, indicating that johnsongrass competition had not been eliminated. Yields relative to the hand-weeded check remained relatively high in all crops when MSMA was used post-emergence, thus indicating that johnsongrass competition had been reduced effectively. When johnsongrass was treated (1) pre-emergence only, (2) pre-emergence plus dalapon post-emergence, or (3) pre-emergence plus MSMA post-emergence, the average yields of sugar/ha as a percent of the hand-weeded check were 49%, 76%, and 92% respectively.

Picloram injured sugarcane in the plant crop, as shown by the relatively low yields, when used either with or without a post-emergence herbicide; the ratoon crops were more tolerant to picloram. Sugar/ha yields in plant cane were also reduced in plots treated with fenac (5 kg/ha) applied in autumn and spring. Terbacil was exceptionally nonphytotoxic to sugarcane as shown by the high yields when used with a post-emergence treatment.

The MSMA treatment did not increase the arsenic content of sugarcane juice in any crop but apparently did increase the arsenic content of bagasse in the first and second ratoon (Table 4). The level of arsenic in bagasse, 0.11 to 0.14 ppm, is considered very low, and approximated that sometimes found in untreated sugarcane (Millhollon[4]).

This study showed that sugarcane can be continuously cropped in fields heavily infested with johnsongrass if an effective herbicide program is used. As of January 1, 1979, MSMA was not registered by the U.S. Environmental Protection Agency for use on sugarcane. Asulam (methyl sulfanilycarbamate) is so registered and should give comparable control of johnsongrass and should injure sugarcane less than either MSMA or dalapon (Millhollon[5]). Factors other than weed control however, may prevent high yields after succession

TABLE 3. Yield of succession-planted sugarcane after treatment with herbicides during a 3-year crop cycle.

Pre-emergence x herbicide and rate kg /ha application	Plant population and yield of sugar as % of the non-treated, weed-free check[2]							
	Plant cane		First ratoon		Second ratoon		3-year total	
	population (stalks/ha x 1000)	yield of sugar (kg/ha)	population (stalks/ha) x 1000)	yield of sugar (kg/ha)	population (stalks/ha x 1000)	yield of sugar (kg/ha)	population (stalks/ha x 1000)	yield of sugar (kg/ha)
				None post-emergence				
Fenac-5.0	66 a	66 a	40 ab	38 a	26 a	19 a	44 a	43 a
Terbacil-1.8	60 a	64 a	25 a	24 a	16 a	14 a	34 a	35 a
Picloram-1.7	70 a	69 a	79 c	79 b	61 b	63 b	71 b	72 b
Fenac-TCA[1]	76 a	80 a	45 b	42 a	17 a	14 a	47 a	48 a
None (weedfree)	100 b	100 b	100 d	100 c	100 c	100 c	100 c	100 c
Mean (excluding weedfree)	68	70	47	46	30	28	49	49
				Dalapon (5.0 kg/ha) post-emergence				
Fenac-5.0	75 ab	78 ab	74 a	74 a	54 a	52 ab	69 a	70 a
Terbacil-1.8	91 bc	89 b	87 ab	87 ab	75 b	76 bc	85 ab	85 ab
Picloram-1.7	67 a	66 a	81 a	87 ab	80 b	86 c	76 a	80 a
Fenac-TCA[1]	79 bc	81 ab	81 a	78 ab	47 a	48 a	71 a	72 a
None (weedfree)	95 c	94 b	102 b	100 b	103 c	102 c	100 b	98 b
Mean (excluding weedfree)	78	79	81	81	64	65	75	76
				MSMA (4.5 kg/ha) post-emergence				
Fenac-5.0	78 b	75 a	98 a	96 a	104 a	101 a	93 a	90 a
Terbacil-1.8	99 c	98 b	93 a	97 a	95 a	93 a	96 a	96 a
Picloram-1.7	59 a	58 a	89 a	92 a	96 a	109 a	81 a	85 a
Fenac-TCA[1]	93 bc	94 b	98 a	102 a	89 a	88 a	94 a	96 a
None (weedfree)	98 c	94 b	100 a	103 a	107 a	114 a	101 a	103 a
Mean (excluding weedfree)	82	81	95	97	96	98	91	92

1 *Treatment consisted of a mixture of TCA (11.2 kg/ha) + silvex (2.8 kg/ha) applied after planting, fenac (7.5 kg/ha) applied the following spring, and mixture of TCA (19.7 kg/ha) + silvex (3.4 kg/ha) applied to the ratoons each spring.*

2 *Yields followed by the same letter within each column of a post-emergence treatment are not significantly different at the 5% level of probability as determined by the Duncan's multiple range test.*

TABLE 4. Arsenic in sugarcane treated with MSMA to control johnsongrass.

	Arsenic content in each crop[1]					
	Juice			Bagasse		
Treatment	Plant cane (ppm)	First ratoon (ppm)	Second ratoon (ppm)	Plant cane (ppm)	First ratoon (ppm)	Second ratoon (ppm)
MSMA-4 kg/ha	0.05	0.05	0.05	0.05	0.14	0.11
Untreated check	0.05	0.05	0.05	0.05	0.07	0.08

1 *Arsenic content for juice is based on fresh weight; that for bagasse is based on fresh weight in the plant cane and first ratoon-crop and dry weight in the second-ratoon crop.*

planting. As experienced in this study, an extended period of dry weather after the intensive soil preparation required for succession planting may prevent good stands of sugarcane. The yield decline that occurred in the second ratoon regardless of herbicide treatment, may have been caused by succession planting or, more likely, by sugarcane mosaic virus that infects most of the CP 52-68 in Louisiana. The various strains of this virus can cause stand and yield losses (Koike and Tippett[2]).

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COMPETENCIA Y CONTROL DE YERBA JOHNSON EN SIEMBRAS SUCESIVAS DE CAÑA AZUCAR

R. W. Millhollon

RESUMEN

Se sembro caña de azucar (hibridos del genero *Saccharum*) directamente siguiendo en tercer retoño de caña de azucar altamente infestado con yerba johnson [*Sorghum halepense* (L.) Pers.] y sin el año de barbecho que es normal en Louisiana. La infestacion de yerba johnson en la nueva cosecha (sin ningun tratamiento de herbicida) fue extremadamente alta, alrededor de 10 plantas con rizomas y 100 plantulas por m² durante el primer año. Se hicieron aplicaciones pre-emergentes con terbacil (3-*tert*-butil-5-cloro-6-metiluracil), fenac [(2,3,6-triclorofenil) acido acetico] o picloram (4-amino-acido 3,5,6-tricloropicolinico), o un tratamiento combinado con TCA (acido tricloroacetico) y fenac aplicado en el otoño despues de la siembra sucesiva y otra vez cada año durante el ciclo de 3 años de cosecha. Estos tratamientos controlaron efectivamente las plantulas de yerba johnson, pero solamente picloran pudo efectivamente suprimir el desarrollo de plantas con rizomas. El control de plantas con rizomas mejoro considerablemente cuando las parcelas tratadas en pre-emergencia tambien fueron tratadas en post-emergencia cada año con MSMA (monosodio aresanto de metaño) o dalapon (acido, 2,2-dicloropropionico); fue mejor el control con MSMA que con dalapon. Los rendimientos promedios de azucar/ha para las tres cosechas, como promedio del testigo desyerbado a mano, fueron de 49% para los tratamientos de pre-emergencia solamente, 76% para los tratamientos de pre-emergencia mas dalapon y 92% para los tratamientos de pre-emergencia mas MSMA. El estudio demostro que bajo las condiciones de Louisiana la competencia de yerba johnson se puede reducir a niveles aceptables en siembra sucesivas de caña de azucar con combinaciones efectivas de herbicidas pre-emergentes y post-emergentes.

THE EFFECT OF VARIOUS HERBICIDAL TREATMENTS ON *DIGITARIA HORIZONTALIS* GROWING IN CANE PLANT

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ABSTRACT

One of the problem weeds of Mauritius is *D. horizontalis* which occurs in all climatic regions of the country. Many chemical treatments have been tested in pre and post-emergence of this grass weed growing in fields of cane plant. In pre-emergence, very good control has been achieved by spraying Metribuzin (Sencor) or a mixture of Diuron and Metribuzin. In post-emergence, good control was obtained with mixtures of Metribuzin or Diuron with Ioxynil + 2, 4-D when the grass was young. However when the weed was at an advanced stage of growth, the only chemical which gave very satisfactory control was Asulam. MSMA did not give adequate weed control whereas mixtures of Metribuzin and Diuron with the non-phytotoxic soil Seppic IIE were completely ineffective.

INTRODUCTION

There are eight *Digitaria* species in Mauritius and seven of them are annuals. The most common species are *D. timorensis* and *D. horizontalis*, both annuals. While the former is easily controlled in pre and post-emergence by Diuron and Diuron + Actril-DS Ionyxil + 2, 4-D respectively, the latter is much resistant. Due to this tolerance, and to the fact that reproduction by seeds is very efficient, the population of *D. horizontalis* has increased constantly and is now a problem in many regions, particularly in the dry zone where Diuron is seldom used. It grows well under different climatic conditions and can withstand severe drought. In Mauritius, it occurs in wet regions where annual rainfall exceeds 2500 mm.It can also grow in very dry regions receiving less than 1000 mm. rainfall.

In absence of sugarcane, *D. horizontalis* is very satisfactorily controlled by a post emergence spray of Roundup *(Glyphosate)* at 3 liters/ha, with the population of the weed decreasing appreciably if spraying is done during or before the flowering stage.

MATERIALS AND METHODS

Two experiments were made to study the effect of various herbicidal treatments in pre and post-emergence of *D. horizontalis.* The experimental

design used in each case was a randomized block where each treatment was replicated three times. Each experimental plot was comprised of four cane rows 6.5 m long. The soil type for both trials was Latosolic Reddish Prairie, a very rocky soil. However, a good derocking was done prior to planting. In both trials the cane variety planted was M 13/56. The herbicides were applied in 650 liters of water per hectare, and sprayed through hand-pump knapsack sprayers.

In the first trial which started at planting time, there were nine herbicidal treatments which were compared to an untreated control. Five of these treatments were sprayed in pre-emergence of cane and weeds. Eleven weeks after planting, four treatments were sprayed in post-emergence of canes and weeds. *D. horizontalis* occurred commonly in all plots, with a ground cover ranging between 25 and 45%. Other weeds which grew in the experimental plots include *Cyperus rotundus, Argemone mexicana, Cleome viscosa, Amaranthus* spp., *Acalypha indica* and *Portulaca oleracea.*

The experimental plots were completely free from weeds at planting time. Pre-emergence treatments were applied two days later. Eleven weeks after planting, the plots which were to be sprayed in post-emergence were surveyed prior to herbicide application and the percentage ground cover of *D. horizontalis* estimated.

The experiment was visited every 10-12 days to observe growth or regrowth of the grass and its phytotoxic effect on cane if any existed.

At the end of the experiment, the population of this problem weed was estimated and the merits of the individual treatments was assesed.

The second trial started when the canes were twelve weeks old. The percentage ground cover of *D. horizontalis* was estimated throughout the experiment. Two pre-emergence and eight post-emergence herbicidal treatments were compared to an untreated control. For the pre-emergence treatments the plots were hand-weeded prior to spraying. The experiment was visited regularly and a final assessment on weed control obtained was made twelve weeks after spraying.

Apart from Seppic 11E which is a non-phytotoxic oil, the chemical formula of all the herbicides mentioned in this paper are given by Martin and Worthing[1].

RESULTS AND DISCUSSION

First trial

The herbicidal treatments applied in pre-emergence of canes and weeds and the assessments of the percentage ground cover of *D. horizontalis* at eleven and twenty weeks after planting are given in Table 1a . In Table 1b

will be found the post-emergence treatments and the percentage ground cover of the grass weed, just before spraying (i.e. 11 weeks after planting) and nine weeks later.

TABLE 1 a and b. Effect of pre and post-emergence herbicidal treatments on *D. horizontalis*

a. Pre-emergence

Herbicides	Dosage (kg a.i./ha)	Mean % cover of *D. horizontalis* 11 weeks after planting	20 weeks after planting
Sencor	4.0	0	2.0
Diuron	4.0	2.0	5.0
Velpar	0.25	3.5	8.0
Velpar	0.5	3.5	6.0
Sencor + Diuron	2.0 + 2.0	0	2.0
Untreated control	—	43.0	83.0

b. Post-emergence

Herbicides	Dosage (kg a.i./ha)	Mean % cover of *D. horizontalis* before spraying	9 weeks after spraying	% kill
Diuron + Seppic 11 E	3.0 + 7 liters	25.0	20.5	18.0
Sencor + Seppic 11E	3.0 + 7 liters	37.0	30.0	18.9
Diuron + Actril-DS	2.0 + 1.2	43.5	21.5	50.6
Sencor + Actril-DS	2.0 + 1.2	40.0	19.5	51.3

The results in Table 1 a indicated that, eleven weeks after planting, a spectacular control of *D. horizontalis* was achieved by all pre-emergence treatments. Only a maximum of 3.5% cover of the weed was observed in the plots treated with Velpar as compared to 43% in the untreated control. Nine weeks later or 20 weeks after planting, this maximum cover had increased to 8.0% whereas that of the untreated control had nearly doubled reaching 83%.

The best treatments were Sencor (Metribuzin) used alone or mixed with Diuron. Only a few weeds namely *C. rotundus* and *A. mexicana* were found in these plots. It was evident that no weeding operation would be necessary as the cane canopy would close in a few weeks later.

The post-emergence treatments were somewhat disappointing with less than 20% kill obtained with the mixture Diuron + Seppic 11E and Sencor + Seppic 11E. However, when Sencor or Diuron was mixed with Actril-DS better weed control of about 50% resulted. It must be pointed out, however, that this percentage represented the early stages of *D. horizontalis*. The older plants were scorched but recovered completely after two weeks.

Second trial

The percentage cover of *D. horizontalis* was estimated in the control and in all plots that were to be sprayed in post-emergence, while the plots to be treated in pre-emergence were hand-weeded. The grass weed was at an advanced stage of growth with most of the plants having already flowered. Twelve weeks after spraying, the percentage cover of the grass was again estimated, and from the figures obtained, the real weed kill was calculated. All these data are given in Table 2.

Asulox (Asulam) used alone at 3 kg a.e./ha has been by far, the best post-emergence treatment, giving an average of 87% kill of the grass while proving safe to the cane. However, when Asulox, at the same rate, was mixed with Actril-DS or with Diuron, the weed control obtained was appreciably lower at about 40%.

Asulox is a slow acting chemical. During the first few weeks after spraying no phytotoxic effect was observed. After 4 to 6 weeks however, the weed showed strong chlorosis and then died. When Asulox was mixed with Actril-DS or with Diuron, scorching of the weed leaves was observed about two weeks after spraying. Eventually, more than 50% of the plants recovered. This rapid phytotoxicity may account for a lower rate of translocation of Asulox to all the plant parts, so the high percentage recovery of the weed.

MSMA at the lower rate has been unsatisfactory, whereas fair control was obtained at the higher rate. The higher rate at the same time caused severe scorching of the cane leaves.

The mixtures of Sencor + Actril-DS and Diuron, + Actril-DS have been disappointing. The leaves of *D. horizontalis* were slightly scorched a few days after spraying but recovery was complete a few weeks later. It must be stressed that if about 50% weed control was achieved in the first trial it was due entirely to the presence of young plants whereas in the second trial all the plants were at an advanced stage of growth.

Practically no weed growth was observed in the plots treated in pre-emergence with Sencor or Diuron.

In conclusion it can be said that there are different possibilities to control *D. horizontalis* very efficaciously in many situations. In pre-emergence of plant canes and weeds a spray of either Sencor at 4 kg a.i./ha or a mixture of Sencor + Diuron (2 + 2) kg a.i./ha will give spectacular results. If weed

TABLE 2. Effect of herbicidal treatments on *D. horizontalis* growing in 10 weeks old plant canes

Herbicides	Dosage kg a.i. or a.e./ha	Mean % cover of D. horizontalis		% kill
		before spraying (A)	12 weeks after spraying (B)	
MSMA	2.0	71.7	56.7	21.0
MSMA	3.0	61.7	28.3	54.1
Sencor + Actril–DS	2.5 + 1.2	51.7	52.0	nil
Diuron + Actril–DS	2.5 + 1.2	60.0	60.0	nil
Asulox	3.0	70.0	9.0	87.1
Asulox + Actril–DS	3.0 + 1.2	61.7	36.4	41.0
Asulox + Diuron	3.0 + 1.0	51.7	31.0	40.0
Diuron	3.0	–	3.0	–
Sencor	3.0	–	1.3	–
Untreated control	–	73.3	90.3	–

* *These figures are calculated as* $\frac{A - B}{B} \times 100$

growth has already occurred, the field can be either hand-weeded and then sprayed with one of the above treatments or sprayed in post-emergence with Asulox at 3 kg a.e./ha.

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EFECTO DE VARIOS TRATAMIENTOS DE HERBICIDAS SOBRE *DIGITARIA HORIZONTALIS* EN CAÑA PLANTILLA

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RESUMEN

Una de las malezas dificultosas en Mauricio es *D. horizontalis,* que se encuentra en todas las regiones climaticas del pais. Se han ensayados muchos tratamientos quimicos en pre- y post-emergencia de esta yerba creciendo en caña de plantilla. En pre-emergencia se ha logrado muy buen control asperjaron Sencor o una mezcla de Diuron y Sencor. Parece que se obtiene buen control en post-emergencia con mezclas de Sencor o Diuron con Actril-DS cuando

la maleza es joven. No obstante cuando la maleza se encuentra en un avanzado estado de desarrollo, el unico producto quimico que controla muy satisfactoriamente es Asulox. MSMA no controla la maleza adecuadamente mientras que mezclas de Sencor y Diuron con el aceite no-fitotoxico Seppic 11E resultaron totalmente inservibles.

POST-EMERGENCE SPOT CONTROL OF GUINEA GRASS (*PANICUM MAXIMUM* JACQ.)

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ABSTRACT

Nine trials were conducted during 1977 and 1978 to study the efficacy of certain herbicides and herbicidal mixtures as post-emergence spot control treatments for guinea grass (*Panicum maximum* Jacq.) growing in cane fields. Of the herbicidal spray solutions tried, buthiadzole at 900 g/100 liters, glyphosate at 1200 g/100 liters and hexazinone at 360 or 540 g/100 liters effectively controlled the weed. The first two mentioned treatments, however, were moderately to severely phytotoxic to cane, causing stunting and/or death particularly in the case of glyphosate. Hexazinone, which only caused marginal stunting of the canes adjacent to treated guinea grass clumps, was observed to be the most suitable treatment for spot control. Its use, however, was limited to times when guinea grass growth was vigorous.

INTRODUCTION

In Trinidad, as in many other countries, guinea grass (*Panicum maximum* Jacq.) is a major weed in sugar cane fields (Holm *et al*[2]). Its unchecked growth for many years near water courses and defunct railway lines has served as reservoir of seed material in this country as has been reported in the case of Queenstand (Javier[3]) and Mauritius (Rochecouste[6]). Pre-emergence and early post-emergence (seedling) control of this weed is fairly easily achieved with a number of common herbicides. However, late-post emergence control is much more difficult and often manual methods, split herbicide applications and even products severely phytotoxic to sugarcane are the only means of control (Anon[1], McAleese[4], Pembroke[5], Rochecouste[6]).

Guinea grass is often not noticed until it has attained a moderate size since its early stages of growth or regrowth is morphologically similar to young sugarcane . Further, this weed is shade tolerant and grows unaffected in cane fields, often within cane stools, regardless of the stage of the crop (Holm *et al*[2], Rochecouste[6]). For these reasons clumps cannot be controlled by the normal broad spectrum herbicidal treatments. In Trinidad, therefore, hand-weeding by digging out was the standard method of control and this proved to be slow and costly. For example, to clear a moderately infested four hectare field containing about 15,000 clumps requires in excess of 30 man-days.

This paper describes a series of trials which were undertaken in order to obtain a cheaper and more effective means of post-emergence control,

than manual digging.

MATERIALS AND METHODS

Nine trials were conducted, four in 1977 and five in 1978. Each trial was set out in a randomized complete block design with four replications. Plot size in each trial was either 10, 15, or 20 guinea grass clumps. Each clump was individually marked by placing a 0.4 m picket next to or within it. In all cases only the marked clumps were considered for purposes of treatment and subsequent assessments.

The herbicidal products used are shown in Table 1. In trials 5 to 9 conducted in 1978 only the two most promising treatments from the trials 1 to 4 of 1977 were retained and applied at two rates each along with two rates of a new product, terbutryn (trade name Igran). Control treatments, either unweeded or hand-weeded, were also included in trials 5 to 9. Herbicide applications were done using knapsack sprayers fitted with hollow cone nozzles having a 45° spray angle. In this way the swath width was relatively narrow and so the likelihood of spraying canes adjacent to the weeds was reduced. Individual clumps were sprayed just to give complete cover but well before the run-off point. Herbicidal treatment rates were taken as the concentration per 100 liters spray solution.

TABLE 1. Description of herbicides used in trials

Common Name	Trade Name	Formulation	Manufacturer	Trial
Ametryne/MSMA	Gesapax Plus 550	18/36%	Ciba-Geigy	4
Buthiadazole	Ravage	75% W.P.	Velsicol	1 to 9
Cyanatryn[a]	Lysofix	40% S.C.	Shell	5 to 9
Glyphosate	Roundup	480 g/liter	Monsanto	1 to 4
Hexazinone	Velpar	90% W.S.P.	Du Pont	1 to 9
Hexazinone/ Diuron	Velpar-K	44/16% W.P.	Du Pont	1 to 2
MSMA	Daconate	35% a.i.	Diamond Shamrock Co.	1 to 3
Terbutryn	Igran	500 g/liter flowable E.C.	Ciba-Geigy	5 to 9

[a]*Withdrawn during 1978.*

Post application assessments were made visually at approximately two-week intervals and scores recorded as the percent of clumps killed. These

assessments were continued for periods ranging from 8 to 13 weeks as conditions permitted. Phytotoxicity to sugarcane was determined by measuring heights of sprayed and unsprayed stalks and calculating the ratio of the former to the latter.

RESULTS AND DISCUSSION

The results of trials 1 to 4 are summarized in Table 2. From these trials, buthiadazole was the most effective treatment giving complete control in every trial. Hexazinone was also very effective since complete guinea grass control was achieved in trials 2, 3 and 4. In trial 1, however, hexazinone gave unsatisfactory control. In this trial, herbicide application was made during the dry season when weeds were growing very slowly and leaves were tougher unlike the case in the latter trials when weed growth was vigorous and leaves were soft. Satisfactory control was obtained with glyphosate in trials 2, 3 and 4 and with hexazinone/diuron in trial 2. However, these two treatments gave little control in trial 1, presumably again because of the application being made before the weed resumed vigorous growth. Ametryne/MSMA in trial 4 and MSMA in trial 3 gave moderate control but their action on larger clumps (those taller than 20 cm) was shortlived, regrowth occurring from the base of the clumps after about four weeks.

TABLE 2. Per cent guinea grass controlled in cane fields with various herbicides in Trials 1 to 4

Trial No.	1	2	3	4
Location	Waterloo Est. 107(154)	Edinburgh PF32 (124)	Edinbugh Est 30(142)	Caroni F105 N(383)
Cane variety	B 41227	HJ 5741	B 41227	B 41227
Date of application	17/5/77	27/5/77	11/6/77	22/6/77
No. of clumps/plot	20	15	10	15

Treatment	Date-concn/100 liters	Per cent weed control Days after application			
		90	84	90	77
Ametryne/MSMA	370 + 730 g	–	–	–	70
Buthiadazole	900 g	98	95	100	100
Cyanatryn[a]	400/800 g	0	5	0	7
Glyphosate	1200 g	9	85	77	92
Hexazinone[a]	360/540 g	39	100	100	100
Hexazinone/Diuron	190/530 g	28	88	–	–
MSMA[a]	875/1050 g	4	0	62	–

[a] *Lower rates were used in Trials 1 and 2.*

With respect to cane phytotoxicity, buthiadazole and glyphosate were severely phytotoxic, particularly glyphosate which caused neighboring canes to be either killed or extremely stunted. Buthiadazole caused moderate stunting of larger plants and death of small tillers. Hexazinone caused slight to moderate stunting in larger shoots depending upon the quantity of spray to which it was subjected. Table 3 summarizes the extent to which the various treatments affected heights of those primary and secondary stalks which could not be avoided during application. Buthiadazole, glyphosate and hexazinone, in descending order, caused the greatest restrictions in stalk heights.

TABLE 3. Phytotoxic effects of herbicides on cane stalks adjacent to treated guinea grass in Trials 1, 2 and 4

Trial No.[a]	1 Waterloo	2 Edinburgh	4 Caroni
Location	Est. 107(154)	PH 32 N(124)	F 105 (383)
Cane variety	B 41227	HJ 5741	B 41227
Date of application	17/5/77	27/5/77	22/6/77

Treatment	Rate-Concn/100 liters	Stalk height % control Days after application		
		165	155	132
Ametryne/MSMA	370 + 730 g	–	–	83
Buthiadazole		75	72	36
Cyanatryn	400/800 g	83	89	71
Glyphosate	1200 g	69	83	48
Hexazinone	360/540 g	83	59	74
Hexazinone/Diuron	190 + 530 g	75	77	–
MSMA	875 g	85	90	–

[a]*Cane growth in trial 3 was poor due to water-logging.*

The results of trials 5 to 9 (conducted in 1978) are summarized in Table 4. Terbutryn was ineffective while buthiadazole and hexazinone were effective at both rates. However, hexazinone at the lower rate gave unsatisfactory control in trials 5 and 6, probably again because of the lack of vigorous growth of the guinea grass at the time of application. The hand-weeded treatments carried out in trials 7, 8 and 9 resulted in varied control from unsatisfactory to good. Despite the care taken to completely remove clumps in all cases, small pieces of the crown which were left behind gave regrowth.

Buthiadazole and hexazinone also caused phytotoxicity to the crop in these trials as was observed in the previous year. Table 5 shows the relative

TABLE 4. Per cent guinea grass controlled in cane fields with various herbicides in Trials 5 to 9

	5	6	7	8	9
Location	Waterloo Est. 11 (348)	Waterloo Est. 12 (349)	Felicite 3 W 6 (253)	Felicite 5 W 9 (230)	Caroni F 105 N (383)
Cane variety	B 41227	B 41227	HJ 5741	HJ 5741	B 41227
Date of application	24/4/78	24/4/78	17/5/78	17/5/78	2/6/78
No. of clumps/plot	10	10	10	10	10

Treatment	Rate-Concn/100 liters	Per cent weed control Days after application				
		60	60	89	89	94
Control	Unweeded	0	0	–	–	–
Control	Manual digging	–	–	62	11	88
Buthiadazole	675 g	83	100	100	100	91
Buthiadazole	1000 g	100	100	100	100	100
Hexazinone	270 g	48	48	100	95	95
Hexazinone	400 g	73	90	100	97	100
Terbutryn	750 g	35	30	0	20	30
Terbutryn	1150 g	40	53	5	8	23

stalk heights due to the various treatments for trials 5, 7 and 8. (Trials 6 and 9 had too little cane to make it worthwhile). In trial 5, where the control was unweeded, heights in all cases exceeded that of the control. In trials 7 and 8 where the controls were hand-weeded, mean stalk heights were inferior in almost all cases. This, therefore, demonstrates that stalk heights are curtailed by both the presence of guinea grass and the use of herbicidal spot spraying.

TABLE 5. Stalk heights of cane adjacent to herbicide treated guinea grass relative to those in unweeded/manual weeded plots in trials 5, 7 and 8

Trial No.[a]	5	7	8
Location	Waterloo Est. 11 (348)	Felicite 3 W 6 (253)	Felicite 5 W 9 (230)
Cane variety	B 41227	HJ 5741	HJ 5741
Date of application	24/4/78	17/5/78	17/5/78

Treatment	Rate-Concn/100 liters	Stalk heights % control after application Days 150	128	128
Control	Unweeded	100	—	—
Control	Manual digging	—	100	100
Buthiadazole	675 g	111	73	93
Buthiadazole	1000 g	101	83	48
Hexazinone	270 g	111	60	84
Hexazinone	400 g	110	88	65
Terbuton	750 g	117	86	90
Terbutryn	1150 g	122	105	112

[a]*Trials 6 and 9 were disrupted before stalk heights measurement by removal of pickets, etc., by intruders.*

CONCLUSIONS

Post-emergence control of guinea grass can be efficiently achieved by the use of buthiadazole at 900 g per 100 liters, glyphosate at 1200 g per 100 liters, and hexazinone at 300 to 450 g per 100 liters. As a spot treatment, however, hexazinone was the most successful because of its relatively lower phytotoxic effect on the cane crop. The phytotoxic effect of this chemical on sugarcane seem to be restricted to stalks which receive direct spray because of their proximity to the weed. On the other hand, spot spraying with buthiadzaole may cause extreme stunting or death of the cane crop. As a substitute for manual digging, the use of hexazinone would greatly reduce operating costs and these would undoubtedly outweigh any losses due to growth reductions. Hexazinone

application for successful control of guinea grass, however, seems to be restricted to periods when the weed is growing vigorously.

Until further work is successfully carried out, which would make it possible to reduce or eliminate the prospect of crop phytotoxicity, and to extend control to slow growing clumps during the dry season, spot application with hexazinone will prove to be a worthwhile method of control.

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CONTROL DE HIERBA DE GUINEA (*PANICUM MAXIMUM* Jacq.) EN POST EMERGENCIA CON APLICACIONES DIRIGIDAS.

G. F. Mason

RESUMEN

Durante 1977 y 1978 se llevaron a cabo nueve ensayos para estudiar la eficacia de ciertas herbicidas y mezclas de herbicidas para controlar la hierba de guinea (*Panicum maximum* Jacq.) creciendo en cañaverales mediante aplicaciones dirigidas en post-emergencia. De todas las soluciones de herbicidas probadas butiadazole a 900 g/100 litros, glifosato a 1200 g/100 litros y hexazinone a 360 o 540 g/100 litros rindieron un control muy bueno de la maleza. Los primeros dos tratamientos mencionados, sin embargo, fueron moderadamente

a severamente fitotoxicos para la caña, impidiendo el crecimiento y/o muerte particularmente en el caso de glifosato. Hexazinone que solamente impidio el crecimiento marginal de las cañas adyacentes a amacollos de hierba de guinea tratada se considero el tratamiento mas apropiado para aplicaciones dirigidas. Su uso, sin embargo fue limitado a las veces cuando el crecimiento de la hierba de guinea era vigoroso.

THE EFFECTS OF SOME POST-EMERGENCE HERBICIDE TREATMENTS ON A RANGE OF SUGARCANE VARIETIES GROWN IN SOUTH AFRICA

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ABSTRACT

A number of post-emergence herbicide treatments were tested for their phytotoxic effects on plant and first ratoon crops of six South African cane varieties. Treatments were applied at twice the standard recommended rates to plant cane but at the recommended rates only to the first ratoon crop. Herbicides were sprayed directly over the sugarcane foliage which had 5-7 leaves unfurled at the time of spraying.

Varying susceptibility of the varieties was evident from early stalk height measurements, in the effects on cane leaves and in the final yield. No good relationship existed however, between early growth retardation and the yield at harvest because of varying extents and rates of growth of the six varieties after treatments.

In the plant crop, herbicide treatments inhibited flowering of varieties N52/219, NCo 293 and N11 and any detrimental effects of the herbicide treatments were masked by low yielding unsprayed plots in which the cane flowered. No flowering occurred in N8, NCo 376 and N55/805. Of these varieties N8 was the most severely affected by alachlor + atrazine + paraquat, diuron + 2,4-D + surfactant (S) and ametryne + 2,4-D + S. N55/805 was more susceptible to alachlor + atrazine + paraquat than to ametryne + 2,4-D + S and was tolerant to diuron + 2,4-D + S. NCo 376 was equally affected by all treatments in terms of tons cane per hectare.

Yield results of the ratoon crop are not yet available but early growth measurements indicate that NCo 293 and NCo 376 are particularly tolerant to diuron + metribuzin. Diuron + hexazinone is similarly to slightly less phytotoxic than diuron + 2,4-D + S on all varieties. N8 is again the most susceptible variety as growth severely retarded by all three treatments. The pattern and degree of phytotoxicity due to diuron + 2,4-D + S in the ratoon crop is very similar to that displayed in the plant crop although the rate applied to the ratoon was only half of that applied to the plant crop;

the ratoon crop was also younger at the time of spraying.

INTRODUCTION

That sugarcane varieties differ in their tolerance to herbicide treatments has been reported by workers in Mauritius, Puerto Rico, Hawaii and South Africa. As early as 1950, Nolla[3] reported that varieties in Puerto Rico differed substantially in their tolerance to applications of 2,4-D. Rochecouste[7,8] in Mauritius found that the most important commercial varieties showed no differences in susceptibility to diuron under normal field conditions but that a difference in tolerance to dalapon and paraquat did exist between varieties. In Hawaii, Osgood *et al*[4] showed that varieties H50-7209 and H53-263 differed in their susceptibility to diuron under both controlled and field conditions.

Richardson[5,6] in South Africa found that the South African varieties NCo 376, NCo 382 and NCo 310 differed in their resistance to various formulations of phenoxyacetic acid. Hence, as soon as possible after a variety reaches the "pre-release" of "bulking-up" stage in the breeding program of the South African Sugar Associations Experiment Station, it is included in trials designed to test its susceptibility to a range of commonly used herbicides. The varieties N52/219, N8 and N11 are relatively new releases and an experiment which included these three and three commonly used varieties, NCo 376, NCo 293 and N55/805, was designed to test their susceptibility to three post-emergence herbicides. A second set of treatments was applied to the first ratoon crop.

EXPERIMENTAL PROCEDURE

The trial was established in November 1977 at Pongola (27°23 south and 31°37′ east) in the semi-arid region of the Eastern Transvaal, using a randomized block design with split plots and four replications. Each plot consisted of six cane rows spaced 1.4 m apart and 8 m long with the two outer rows and a 1 m section from the ends of each row being discarded at harvest, leaving a net plot of 4 rows x 6 m. Each row was planted with a double line of 5-eyed setts, which had been dipped in Benlate fungicide prior to planting.

Single superphosphate fertilizer was applied in the furrow at planting and the cane was subsequently topdressed with nitrogen and potassium in the form of 1.0.1 (47). The soil was sandy clay loam of the Shorrocks series containing 8.5% silt, 65% sand and 26.5% clay. The trial was irrigated with 60 mm of effective water from overhead sprinklers every 25 days, or as soon thereafter as the soil moisture deficit reached 60 mm. The varieties used were NCo 376, NCo 293, N52/219, N8, N55/805 and N11.

The treatments used and the rates of herbicide application were:

1. Unsprayed control

2. 3.84 kg ai alachlor + 2.0 kg ai atrazine + 0.4 ae paraquat
3. 4.0 kg ai diuron + 2.88 kg ae 2,4-D + S
4. 3.0 kg ai ametryne + 2.88 kg ae 2.4-D + S

A non-ionic surfactant, Agral 90, was used where indicated at a rate of 0.2% volume for volume. The rates of herbicide used are twice those normally recommended because a safety factor of x 2 is considered desirable in the field.

The treatments were applied directly over the cane rows by means of a lever-operated knapsack sprayer fitted with a Spraying Systems TK5 floodjet. The output was 270 1/ha using a pressure of 1.25 bars. The cane was sprayed in January 1978 and the stage of growth of cane then was on average :

NCo 376 — 0.6 m canopy height and 7 - 8 leaves unfurled per shoot.
N52/219 — 0.55 m canopy height and 6 - 7 leaves unfurled per shoot.
N55/805 — 0.6 m canopy height and 6 - 7 leaves unfurled per shoot.
NCo 293 — 0.6 m canopy height and 6 - 7 leaves unfurled per shoot.
N8 — 0.55 m canopy height and 7 - 8 leaves unfurled per shoot.
N11 — 0.55 m canopy height and 6 - 7 leaves unfurled per shoot.

The plant crop was burnt at harvest in November 1978, the tops raked off the plots and the first ratoon allowed to regenerate. A new set of treatments was applied in January 1979 in the same manner to the ratoon crop. The four new treatments were applied in such a way that each new treatment was sprayed over four plots which had previously received one each of the earlier treatments in order to discount any residual treatments, effects that might exist.

The ratoon treatments and rates were:

1. Unsprayed control
2. 2.0 kg ai diuron + 1.44 kg ae 2.4-D + S
3. 1.6 kg ai diuron + 1.4 kg ai Sencor
4. 1.0 kg ai diuron + 0.675 kg ai Velpar

The leaf height of the ratoon crops at the time of spraying was less than that of the plant crop, being on average 0.45-0.5 m.

Both trials were maintained weed-free by means of hand weeding and mechanical cultivation to prevent any weed competition throughout the crop period. Growth measurements in the form of stalk counts and height measurements, were made at regular intervals. Counts were conducted on one net row of each plot and stalk heights to the top visible dewlap were measured on 20 randomly selected stalk in two net rows.

In November 1978, when the trial was 11.8 months old, it was harvested and the cane in the net plots weighed by means of a tractor mounted scale and grab. Twelve stalks per plot were taken at random for analysis and cane quality determination using the formula ers % cane = $1.05 - 0.485M - 0.057F$, where S = sucrose, N = non-sucrose, F = fiber and the coefficients are factors

accounting for average sucrose losses due to non-sucrose and fiber, respectively, in South African sugar factories.

RESULTS

Plant crop

a. Leaf symptoms

Visual ratings of leaf scorch were made seven days after treatments were applied and the mean results are presented in Table 1. Ratings are based on the European Weed Research Society (EWRS) scoring system of 1-9 where 1 = no effect and 9 = dead.

TABLE 1. Mean visual ratings* of leaf scorch taken 7 days after herbicide application

Variety \ Treatment	Alachlor + atrazine + paraquat	Diuron + 2, 4-D + S	Ametryne + 2, 4-D + S
N55/805	5.8	2	3
NCo 376	6	2	3.3
N11	6.3	2	3.5
NC_0 293	6	2	3.8
N52/219	5.5	2.8	4
N8	6.3	3.3	4

* *EWRS rating scale of 1-9 where 1 = no effect, 4 = just acceptable, 5 = just unacceptable and 9 = dead*

Symptoms due to alachlor + atrazine + paraquat were characteristic of paraquat effects and there was necrosis and chlorosis of leaves contacted by the spray solution. Diuron + 2,4-D + S produced a light chlorosis while ametryne + 2,4-D + S caused chlorosis and some characteristic bronzing (speckled brown necrotic spots on the leaf blades). All visual effects of the treatments on the cane leaves had disappeared two months after spraying.

Greater differences in leaf scorch were apparent between treatments than between varieties although N8 and N52/219 were affected slightly more than other varieties. The severity of the treatments was in relation to their contact action. The paraquat treatment was most severe, followed by the ametryne treatment and finally the diuron treatment which has less contact action.

b. Stalk heights and cane yield

Stalk heights taken one month after spraying and at harvest time, and sugarcane yields in tons/ha, all expressed as percentages of the stalk heights and cane yield in the unsprayed control plots are shown for the three treatments in Figures 1a, b and c.

1. *Early stalk heights*

There were large varietal differences in the early effects of herbicide treatment on stalk length. In Fig. 1b it can be seen that N55/805 showed virtually no reduction in height while N8 was severely stunted after treatment with diuron + 2,4-D + S. Stalk heights were reduced to some extent in all varieties.

The effect on varieties differed between treatments. N55/805 and NCo 293 were far more severely affected by paraquat or ametryne treatments than by treatments with diuron + 2,4-D + S. N11 was more susceptible to paraquat than to either ametryne or diuron treatments.

2. *Stalk heights at harvest*

After the initial retardation of growth stalk height depressions due to treatments decreased proportionately as demonstrated in Figs. 1a, b and c. Stalk heights were commonly reduced by 40% one month after spraying and at harvest were in most cases greater than 90% of that in the unsprayed control plots. Only NCo 293 showed no difference in stalk height after treatment with diuron + 2,4-D + S and ametryne + 2,4-D + S, but there were differences after treatments with alachlor + atrazine + paraquat

Thus early height reductions were a poor indicator of height reductions at harvest as differences became less obvious with time. Stalk heights at harvest were only slightly depressed in treated plots of varieties N52/219, NCo 293, and N11 and this could be attributed to the flowering which occurred in untreated plots of these varieties.

3. *Cane yield*

The yield of sugarcane in tons/ha expressed as a percentage of the yield from unsprayed control plots differed substantially between varieties while a difference between treatments within a variety occurred to a lesser extent. The yield of N8 was reduced more than that of NCo 376 by all treatments. N55/805 was more severely affected by alachlor + atrazine + paraquat than by diuron + 2,4-D + S.

The results show that cane yield followed a fairly similar pattern to that of stalk height at harvest in varieties NCo 376 and N55/805 but not in the other four varieties. For N8 stalk counts as well as heights were depressed by treatments and the yields were correspondingly lower. For varieties N52/219, NCo 293 and N11, treated plots surprisingly yielded more than did unsprayed control plots, although stalk heights at harvest were still slightly depressed.

The effects of flowering, which occurred mainly in untreated plots of these varieties, may have confounded the herbicide effects, and consequently caused the poor relationship between yield and final stalk height.

c. *Flowering*

Extensive flowering occurred in the unsprayed control plots of varieties NCo 293, N52/219 and N11, while in the treated plots flowering either did not occur or was severely delayed. Figs. 2a, b and c show the percentage of flowered stalks in each treatment five, four, three, two and one month before harvest.

Fig. 2a shows the extent of flowering in unsprayed control plots of N11 and the inhibition and delay in flowering in treated plots. Emergence of the inflorescence in treated plots was delayed about three and a half months, after which the trend followed that in untreated plots. Alachlor + atrazine + paraquat inhibited flowering more than did the other treatments. A similar trend occurred in variety NCo 293 as shown in Fig. 2c but N52/219 showed far less flowering and reached a peak two months before harvest.

d. *Yield and crop characteristics*

The yield in terms of tons cane/ha, estimated recoverable sugar as a percent of cane (ers % cane) and estimated recoverable sugar (ers) in tons/ha of each variety, together with the stalk heights and counts taken at harvest are presented in Table 2.

1. *Tons cane/ha*

N8 was the most severely affected by all three treatments . The yield of N55/805 was depressed to a statistically significant degree by alachlor + atrazine + paraquat but not by other treatments. In all the varieties which flowered the treated plots yielded higher than untreated control plots, but this did not reach a level of statistical significance except for the effect of diuron + 2,4-D + S on N11.

Inspite of yield reductions due to treatments NCo 376 performed better than all other varieties. Untreated control plots of N52/219, NCo 293 and N11 could be expected to have performed better had no flowering occurred, but they are unlikely to have outyielded variety NCo 376.

2. *Ers % cane:*

Statistically significant reductions in ers % cane were caused by all treatments on N8 but only by ametryne + 2,4-D + S on NCo 376 and N52/219. A trend towards lower ers % cane in treated plots existed for all varieties in all treatments except for diuron + 2,4-D + S on N11.

3. *Ers tons/ha*

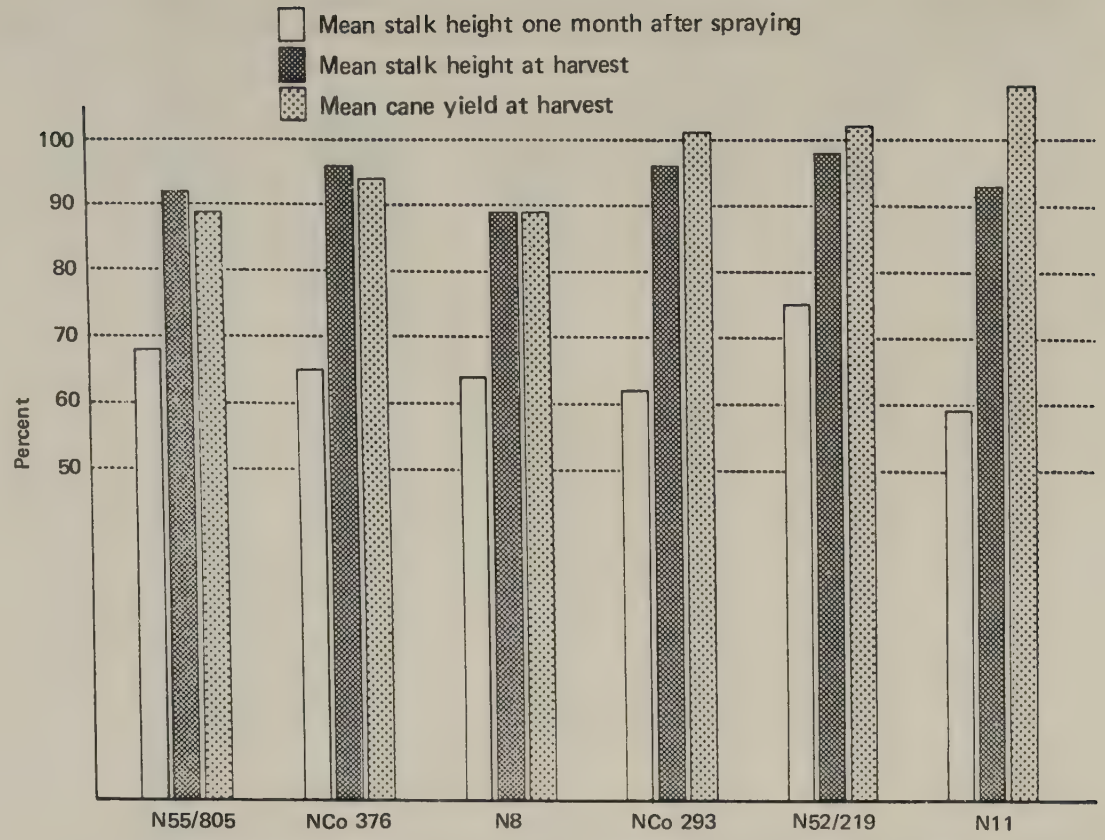


FIGURE 1. The effect of treatment with alachlor + atrazine + paraquat on stalk heights and cane yeild (t/ha) expressed as a percentage of stalk heights and cane yield from unsprayed control plots

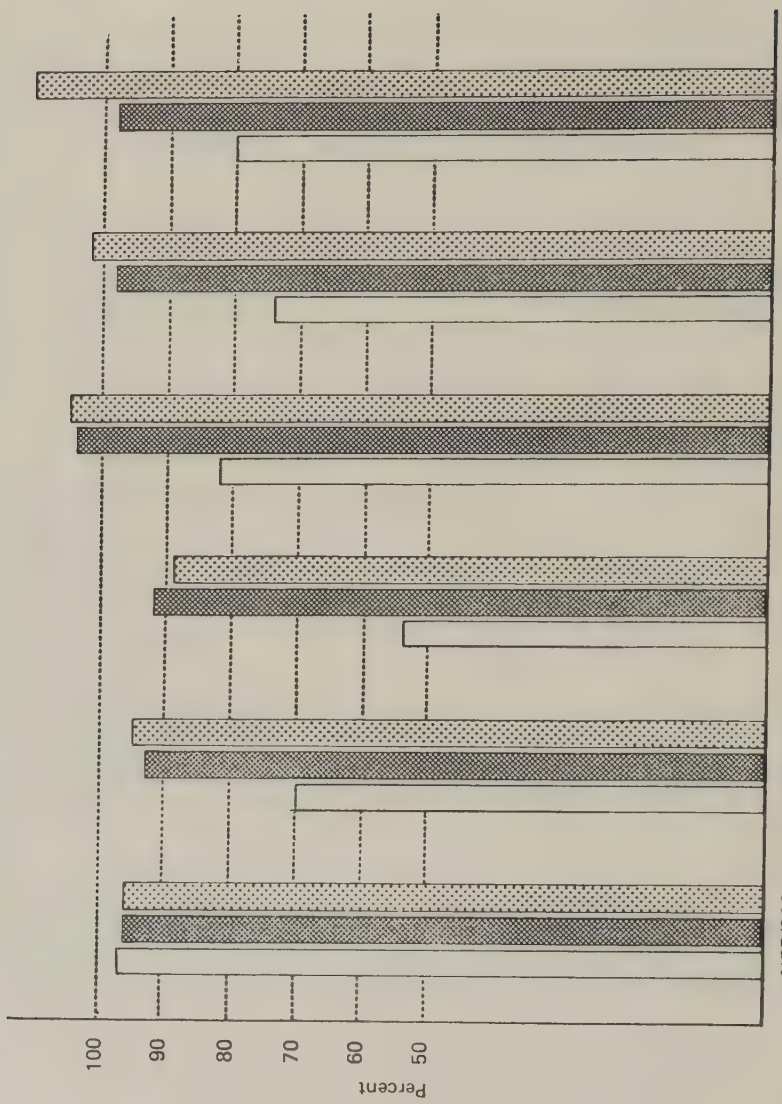


FIGURE 1b The effect of treatment with Diuron + 2, 4 – D + S on stalk heights and cane yield (+/ha) expressed as percentage of stalk heights and cane yield from unsprayed control plots.

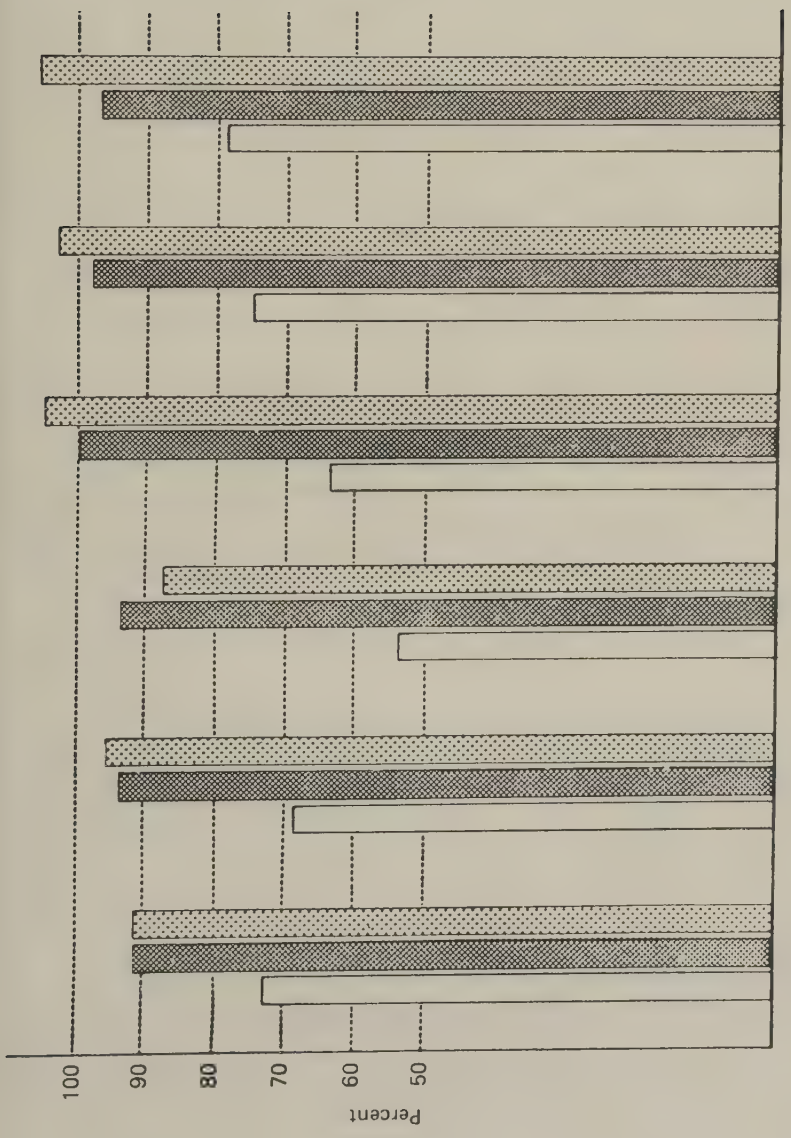


FIGURE 1c. The effect of treatment with Ametryne + 2, 4 — D + S on stalk heights and cane yield (+/ha) expressed as percentage of stalk heights and cane yield from unsprayed control plots.

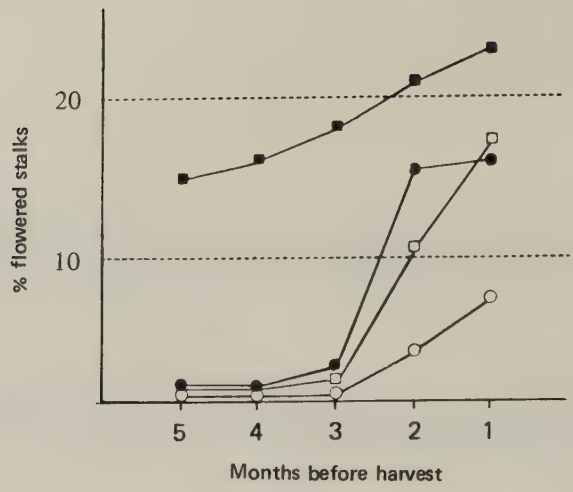
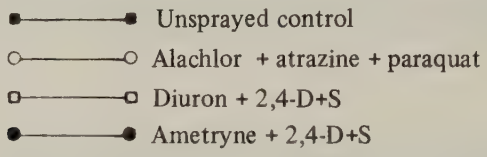


FIGURE 2a Percentage flowered stalks of N11 after treatment.



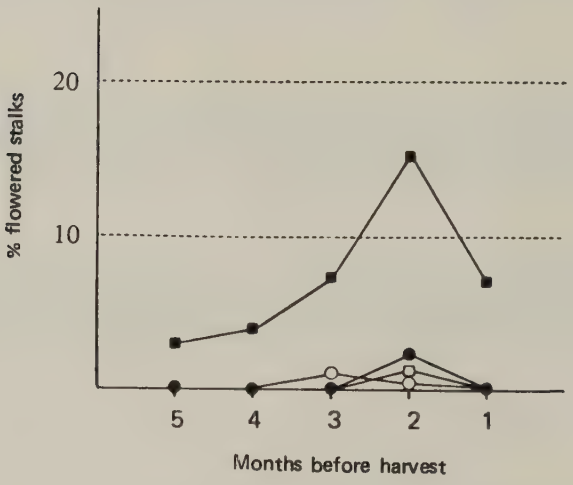


FIGURE 2b. Percentage flowered stalks of N52/219 and after treatment.

The combined effects of lower tons cane/ha. and ers. % cane caused a statistically significant reduction in ers tons/ha due to all treatments on NCo 376. In all treated plots variety N8 showed reductions in all yield parameters. Only

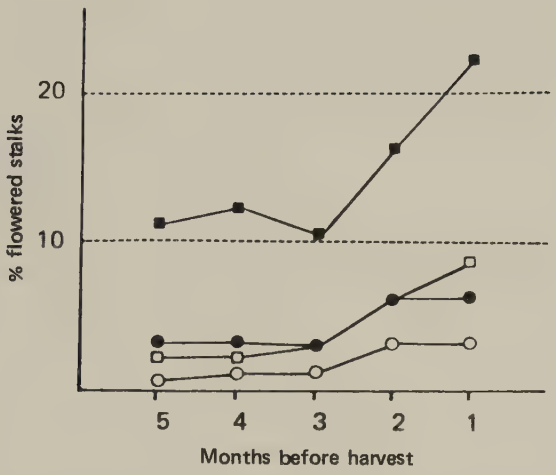


FIGURE 2c Percentage flowered stalks of NCo 293 after treatment

in plots treated with alachlor + atrazine + paraquat were ers yields of N55/805 reduced to a statistically significant degree. In general the lower ers % cane of the sprayed varieties which were prone to flowering tended to offset the higher tons cane, and the resultant ers yields (tons/ha) were little altered from unsprayed control.

4. *Stalk heights*

The stalk heights of cane in the unsprayed control plots of all varieties were superior at harvest to those of cane in all the treated plots except where diuron + 2,4-D + S was applied to NCo 293. These height differences were not visible but do nevertheless indicate that treatment effects have not disappeared completely.

5. *Stalk counts*

Stalk counts were very variable and at harvest no large differences were apparent between varieties NCo 376, N55/805 and NCo 293. Stalk counts of N8 were depressed by all treatments while those of N11 were depressed by ametryne + 2,4-D + S and to a lesser extent by diuron + 2,4-D + S. Stalk counts of N52/219 were increased by all treatments.

2. *1st Ratoon crop*

Stalk heights of the first ratoon crop taken one month after treatment and expressed as a percentage of heights in unsprayed control plots, are presented in Fig. 3.

TABLE 2. Plant crop yields of six varieties which have been sprayed with three different herbicide mixture.

Variety	Treatment	Cane t/ha	Ers % cane	Ers t/ha	Height cm	Population 000/ha
NCo 376	Control	139	12.2	17.0	240	137
	Alachlor+atrazine+paraquat	130	11.6	15.0*	230	130
	Diuron + 2-4-D + S	132	11.5	15.2*	223	135
	Ametryne + 2,4-D + S	133	11.0	14.6**	225	128
N52/219	Control	115	13.1	15.1	242	77
	Alachlor+atrazine+paraquat	117	12.8	14.9	238	86
	Diuron + 2,4-D + S	117	12.2	14.3	236	90
	Ametryne + 2,4-D + S	118	12.1*	14.3	237	92
N8	Control	112	11.9	13.4	255	120
	Alachlor+atrazine+paraquat	100*	10.1**	10.2**	226	102
	Diuron + 2,4-D + S	100*	10.9*	10.9**	234	98
	Ametryne + 2,4-D + S	98**	9.7**	9.5**	239	95
N55/805	Control	113	11.8	13.3	223	99
	Alachlor+atrazine+paraquat	101*	11.3	11.3*	206	97
	Diuron + 2,4-D + S	109	11.3	12.3	213	101
	Ametryne + 2,4-D + S	104	11.5	12.0	205	97
NCo 293	Control	112	11.8	13.2	225	98
	Alachlor+atrazine+paraquat	113	11.2	12.6	217	98
	Diuron + 2,4-D + S	118	11.4	13.6	233	98
	Ametryne + 2,4-D + S	118	11.3	13.3	224	106
N11	Control	98	11.0	10.8	242	105
	Alachlor+atrazine+paraquat	106	10.7	11.4	226	102
	Diuron + 2,4-D + S	109*	11.1	12.1	236	94
	Ametryne + 2,4-D + S	103	10.7	11.0	235	90
	L.S.D. (0.05)	9.75	0.97	1.5		
	L.S.D. (0.01)	13.47	1.3	2.1		

* *L.S.D. (0.05) from control*
** *L.S.D. (0.01) from control*

Again marked differences were apparent in the effects of herbicide treatments on the six varieties. NCo 376 and NCo 293 were noticeably less affected by diuron + metribuzin (Sencor) than were other varieties. Varieties N55/805, NCo 293 and N11 which showed greater susceptibility to scorch treatments in the plant crop were more severely affected by diuron + hexazinone (Velpar) than by diuron + 2,4-D + S which caused less foliar scorch Other varieties were more susceptible to diuron + 2,4-D + S. The pattern of the effects of diuron + 2,4-D + S on the first ratoon (sprayed at half the plant cane dose and at a younger stage of growth) were very similar to those in the plant crop. Hence it appears that a double dose was little more severe than a single dose and that ratoon cane was only slightly less susceptible than plant cane.

DISCUSSION

Leaf scorch

Yield reductions in N55/805 and NCo 293 appear to show a similar trend in terms of the degree of leaf scorch. These varieties showed marked tolerance to diuron + 2,4-D + S which caused few symptoms of leaf scorch while ametryne + 2,4-D + S and particularly alachlor + atrazine + paraquat caused severe leaf symptoms and corresponding yield reductions. Yields of N8 and NCo 376 were reduced to a similar extent by both diuron + 2,4-D + S and alachlor + atrazine + paraquat and hence did not show the same trends as those of N55/805 and NCo 293. It would thus be misleading to regard the degree of leaf scorch as an indication of subsequent yield loss except possibly for varieties N55/805 and NCo 293.

Stalk heights

The large depression in stalk heights caused by all treatments soon after spraying became less noticeable with time and this confirms the results obtained by Richardson[6] with various 2,4-D formulations on NCo 376, NCo 310 and NCo 382. The length of time from spraying to harvest and the growth conditions during that period influenced the ultimate treatment effects. Although the plant crop in this experiment was harvested at only 11.8 months of age and was planted in late summer, the growth after spraying masked the treatment effects.

In most situations in the South African sugar industry sufficient time would be available for the effects of timely sprays to have virtually disappeared by harvest. It is interesting however, that none of the varieties tested except NCo 293, after treatments with diuron + 2,4-D + S, recovered completely, indicating that some effect, no matter how slight, is likely to persist due to early growth retardation.

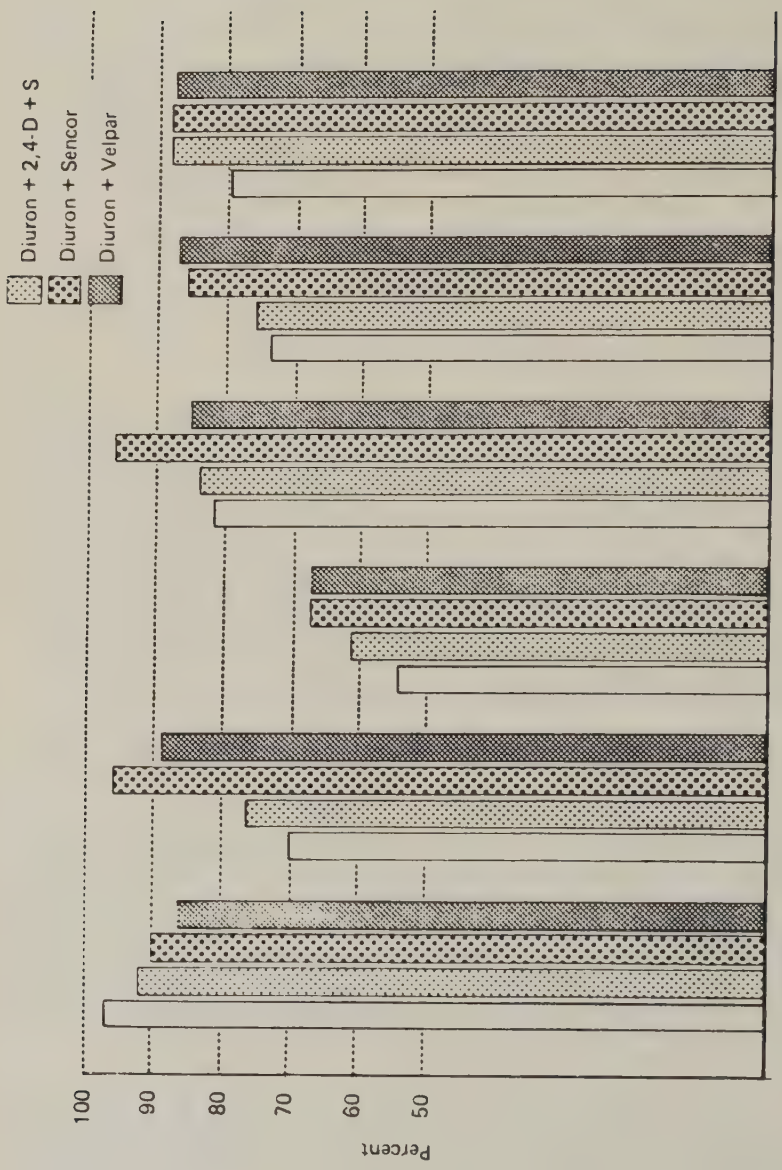


FIGURE 3. The effect on stalk heights one month after spraying three different herbicide treatments to the first ratoon of six varieties, expressed as a percentage of stalk heights in the unsprayed control plots. (Plant crop results after treatment with diuron + 2,4-D + S are also included □)

Stalk counts

Osgood *et al*[4] have reported statistically significant effects on stalk counts and stalk diameter in three varieties due to treatment with both diuron and ametryne applied at 10.0 kg ai/ha. Results in the trial reported here confirm that stalk counts in some varieties, namely N8 and N52/219, can be affected by treatments. Stalk mass was increased in N11 and decreased in N52/219 by all treatments. Thus final yield would be difficult to predict from only one of these yield parameters. Yield may be affected by the degree of foliage scorch, the effect on population and stalk mass.

Plant versus ratoon cane susceptibility and stage of spraying

Plant cane is generally regarded as being more susceptible to herbicide treatments than is ratoon cane. Richardson[5] reported that visual damage was far more severe on plant than on ratoon cane from treatment with 2,4-D, but that no conclusive evidence of yield reduction was present at harvest. No differences between plant and ratoon cane were evident in this trial despite the ratoon crop having received only half the herbicide dosage applied to the plant crop. This comparison is however restricted to the effects on stalk height only and was also made in two successive years when different growth conditions may have prevailed.

Spray application

Richardson[5] reported that marked differences may occur in yield depending on the stage of cane at spraying and whether the spray is directed across the interrow or not. Once cane has reached 40 cm in height directed sprays are far less damaging due to the reduced contact with cane foliage. In this trial double applications over the row produced small reductions in yield in N55/805 and NCo 376. Thus, directed sprays at single rates could be expected to have negligible effects on cane yield and the danger of damage to cane from any of these treatments applied correctly should be minimal.

Ers % cane

Although reductions in ers % cane have been noted due to herbicide treatments[8], seldom have they reached a level of statistical significance. In this trial however, ers % cane was generally depressed and in some instances severely so. Because herbicide treatments inhibited flowering it is impossible to differentiate between the effects of flowering and herbicides on cane quality in varieties N52/219, NCo 293 and N11.

Flowering

The incidence of flowering in the South African sugar industry is erratic due to variable climatic conditions but it is more common in the warmer, irrigated, northern region. Flower initiation occurs during the first half of March and it is interesting to note the strong inhibiting effect on flowering

caused by the herbicide treatments which were applied two months earlier in January.

Since a reduction in stalk height was evident in treated plots of all flowered varieties before initiation took place, it could be expected that treated plots would yield lower than untreated plots or at least no higher. Thus it appears that flowering was responsible for the reduction in yield in the untreated plots. The extent of the reduction due to flowering cannot be accurately assessed but the mean increase in treated plots of the flowered varieties was 5 tons cane/ha and the mean decrease in treated plots of unflowered varieties was 9 tons cane/ha. Thus the mean reduction due to flowering could have been as much as 14 tons cane/ha.

General

In the ratoon crop Sencor, which is one of the safest treatments on NCo 376, the major variety used in the South African sugar industry, was severe in its effect on N8. Stunting was also noticeable in N52/219, N11 and N55/805 from diuron + Sencor. It has been reported from Taiwan that many varieties were sensitive to metribuzin (Sencor) when this was sprayed over cane at the three to four leaf stage (Yuh Huong-jaan[9]). This effect lasted for only six weeks however. It is clear that it is dangerous to extrapolate results from one variety to another, and any new variety should be tested for its tolerance to herbicide treatments before these are used generally.

CONCLUSIONS

The six varieties used in these trials showed very variable susceptibility to herbicide treatments and so the effects on any new variety cannot be easily predicted. Thus continued screening of new varieties for herbicide susceptibility is essential.

Of the varieties tested N8 was most severely affected by all herbicide treatments. For this variety pre-emergence treatments would be expected to show less phytotoxicity and are therefore to be preferred to treatments which are sprayed after the crop emerges.

Of the varieties which did not flower the order of increasing susceptibility to herbicides in terms of tons ers/ha was N55/805, NCo 376 and N8. N55/805 is more susceptible to contact chemicals than treatments such as diuron + 2,4-D + S. Thus paraquat and to a lesser extent ametryne should be used with great care on varieties such as N55/805.

NCo 376, currently the most important variety in the South African sugar industry, was susceptible to all the treatments tested except diuron + Sencor. Despite the yield reductions caused by the herbicide treatments however, NCo 376 substantially outyielded the other five varieties whether sprayed or not.

Thus in general, varieties differ substantially in their susceptibility to post-emergence herbicides and different herbicide treatments may have different effects on any one variety. No general relationship existed between leaf scorch or early stalk height reduction and final yield for the six varieties tested. Ratoon cane appeared to be only slightly less susceptible to herbicides than plant cane although yield results are not yet available to confirm this.

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LOS EFECTOS DE TRATAMIENTOS POST-EMERGENTES DE HERBICIDAS SOBRE DISTINTAS VARIEDADES DE CAÑA DE AZUCAR CULTIVADA EN SUD AFRICA

P. E. T. Turner

RESUMEN

Se ensayaron varios tratamientos de herbicidas post-emergentes en cuanto a sus efectos fitotoxicos en cosecha de plantilla y primer

retoño de seis variedades de caña de Sud Africa. Los tratamientos se aplicaron a dosis de dos veces la recomendacion estandar en la plantilla pero solamente a la dosis recomendada en caso del primer retoño. Los herbicidas se asperjaron directamente sobre el follaje de la caña de azucar que al momento de la aplicacion tenia 5-7 hojas extendidas.

Era evidente que las variedades variaban en susceptibilidad como se manifesto a traves de medidas de altura de los tallos, en los efectos sobre las hojas de la caña y en el rendimiento final. Sin embargo no hubo una buena relacion entre retardacion de crecimiento inicial y el rendimiento al ser cosechado debido a que las variedades eran muy variables en tanto a crecimiento despues de ser tratadas.

En la plantilla los tratamientos con herbicidas impidieron la floración de las variedades N 52/219, NCo 293 y N 11 y cualquier efecto perjudicial del herbicida fue enmascarado por las parcelas no tratadas de bajo rendimiento donde las cañas florecieron. Las variedades N 8, NCo 376 y N 55/895 no florecieron. De estas variedades la N 8 fue mas severamente afectada por alaclor + atrazina + paraquat, diuron + 2,4-D + surfactante (s) y ametrina + 2,4-D + S N 55/805 fue mas susceptible a alaclor + atrazina + paraquat que a ametrina + 2,4-D + S y fue tolerante a diuron + 2,4-D + S. NCo 376 fue igualmente afectada por todos los tratamientos en terminos de toneladas de caña por hectarea.

DISSEMINULES OF *CYPERUS ROTUNDUS L.* IN SUGARCANE *SACCHARUM SPP.* L. STALKS AND RHYZOMA

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ABSTRACT

The occurrence of *Cyperus rotundus* L., in sugarcane stalks and rootstock of variety CB41-76 was reported. The presence of disseminules of *C. rotundus* in sugarcane stalks is not associated with chemotropism effects, unless by a casual error. When the cane stalks did not develop shoots, *C. rotundus* is present, and on emitting shoots, *C. rotundus* is in dormancy. Plants produced from both *C. rotundus* L. and cane having this phenomenon were normal.

INTRODUCTION

Cyperus rotundus is the main species in the list of the 13 worst sugarcane weeds and world worst weeds (Holm *et al*[11]). This species is found in 92 countries and 52 cropping cultures. It is practically found in all sugarcane producing countries (Arevalo[1, 2, 3, 4]; Holm[11] and Rochecouste[14]). In Brazil, *C. rotundus* is the main species in the list of the 12 worst sugarcane weeds (Arevalo[6]).

Hilton[9, 10] considers *C. rotundus* a non-important species in sugarcane since its relative density is not high. In spite of this Arevalo *et al*[1,2,3], determined in Tucuman, Argentina, that the interference of *C. rotundus* produce sugar losses of 26 kg per ha per competition day.

On the other hand, the damaging behavior of *C. rotundus* is reported throughout the world. It has a great capacity for reproduction (Chase *et al*[8]). In the United States (Rao[13]), a tuber gave 146 tubers in 3.5 months. In Israel, Horowitz[12] found 1,000 tubers per m^2 in soil from a single tuber in 20 months. As *C. rotundus* is a species difficult to control it is important to determine the varieties most tolerant and most susceptible to its competition. In Argentina, Arevalo *et al*[1, 2, 3], found that the sugarcane varieties NA56-79 and NA56-30 are very sensitive to *C. rotundus* competition. However, NCo310 and Tuc56-19 proved to be tolerant. Sugar losses per ha were highly significant when *C. rotundus* developed together with the cane over 60 days. Though this may be the first time that the presence of disseminules of *C. rotundus* in sugarcane stalks and rhyzoma is reported in sugarcane literature, the phenomenon was already found in small potato tubers (*Solanum tuberosum* L.) by Trippi and Tizio[16], during the year of 1961, in Mendoza, Argentina. In Argentina, it is possible to find tuber roots of *Ipomea batatas* Poir., and tubers of *S. tuberosum*

L. invaded by rhizomes of *Cynodon dactylon* (L.) Pers.

OBSERVATIONS

The occurrence of disseminules of *C. rotundus* in sugarcane stalks and rootstock was casually revealed in a sample of *C. rotundus* infestation, at the Sugarcane Experiment Station in the Southern Regional Coordination Service of PLANALSUCAR, in Araras, Sao Paulo, Brazil. (Figs. 1, 2 and 3). This was observed in an autumn planted field in 1978, of the variety CB41-76, cultivated in an Ortho dark-purple Latosol soil. On this occasion, disseminules of *C. rotundus* in 5 sugarcane stalks and a single rootbock were found.

FIGURE 1. Tuber of *C. rotundus* in the sugarcane stalk of the variety CB41-76. (Original, 1978).

FIGURE 2. Tuber of *C. rotundus* in the sugarcane stalk of the variety CB41-76. (Original, 1978, x 3).

FIGURE 3. Basal bulb of C. *rotundus* in the sugarcane rhyzoma. The emergence of the seedling of C. *rotundus* can be observed from the basal bulb (Original, 1978).

DISCUSSION

Betria[7] stated that the formation of the basal bulb of *C. rotundus* is associated with the light impact on the emergence of shoot. There is a phototropic reaction (formation of the basal bulb), when the shoot emerges and comes in contact with red light. According to this biological mechanism, a rhizome of *C. rotundus* penetrated into the cane stalk or rootstock and developed inside it, giving rise to an orthotropic branch which on emergence received the phototropic stimulus. This induces the formation of the basal bulb in the cane stalk or rootstock, and explains the presence of the basal bulb of *C. rotundus* in the cane stalk or rootstock.

The said phenomenon could also be explained by the hypothesis of Trippi and Tizio[16], who studied the formation of the tubers of *C. rotundus* in the tubers of *Solanum tuberosum* L. They concluded that a rhizome of *C. rotundus* penetrates in the tuber of *S. tuberosum* and when it forms suffer the influence of a growth inhibition agent, its apical meristem ceases to function and the tuber is formed. Applying this hypothesis to sugarcane, the rhizome of *C. rotundus* would penetrate in the cane stalk, ceasing its apical meristem growth due to an inhibition agent effect, thus forming the tuber which developed in it. Apparently, the penetration of rhizomes of *C. rotundus* in sugarcane stalks and rootstock is simple, not involving chemotropic phenomena.

A curious aspect of this phenomenon is when the cane bud was developing into a primary shoot, the tuber of *C. rotundus* was in it dormant. However, when the tuber of *C. rotundus* was germinating the cane bud was not. Further research has to be done in order to clarify the observed phenomenon.

CONCLUSION

A rhyzoma of *Cyperus rotundus* L., penetrated in the sugarcane stalk or rhyzome casually, where a basal bulk or tuber was formed. When the cane stalk is developing a primary shoot, the disseminule of *C. rotundus* is in dormancy, and when the disseminule of *C. rotundus* is developing a shoot, the cane stalk is in dormancy. The plants produced from both *C. rotundus* L. and cane presenting this phenomenon were normal.

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DISEMINULOS DE *CYPERUS ROTUNDUS* L. EN EL INTERIOR DE COLMOS E RIZOMAS DE CAÑA DE AZUCAR *SACCHARUM SPP* L.

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RESUMEN

El presente trabajo informa acerca del hallazo de diseminulos de *Cyperus rotundus* L. en el interior de colmos e rizomas de caña de azúcar, variedad CB41-76.

Esta observación, fue efectuada en Araras, Sao Paulo, Brasil en un suelo latosol rojo oscuro Orto, naturalmente infestado por *Cyperus rotundus*. donde se planto caña en Abril de 1978.

La presencia de diseminulos de *C. rotundus* L. en el interior de colmos de caña, no estando asociado a efectos de quimiotropismo, sino a un hecho causal.

Cuando el tolete de caña, no presentaba brote, lo tenia el *C. rotundus* y cuando el tolete presentaba brote no lo tenia el *C. rotundus*.

Las plantas de *C. rotundus* y las plantas de caña nacidas donde presentaban este fenomeno, eran normales.

THE SUITABILITY OF THE SOILS OF LOWER MESOPOTAMIAN PLAIN FOR SUGARCANE CULTIVATION

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ABSTRACT

Three typical and widely-distributed pedons of the Lower Mesopotamian Plain (Southern Iraq) were investigated for their morphology and physico-chemical properties in order to evaluate their suitability for growing crops, especially sugarcane, and to extrapolate their realizable and actual cane yields. The soils (Aquertic and Typic Torrifluvents) show stratification of sediments with platy (sedimentary) structures and imperfect drainage conditions. They are highly calcareous, silty-clay-loam to silty-clay, slight to moderately-saline and develop cracks on drying. Whereas the surface soils have favorable physical conditions for the seeding of most crops, the subsurface soils have unfavorable physical properties. A significant negative correlation between cane tonnage and EC (1:1) has been established and accordingly an ED of 2.8 seems critical at which cane yields decline by 25%. Using the parametric approach, the levee-soils have been found to be moderately-suitable for sugarcane plantation followed by those in silted-basin; the silted 'Haur' soils are the least suitable. Progressive ratooning showed an increase in actual average from 45 to 56 TC/ha. However, this increase was more significant in levee-soils (74.6 TC/ha.) than in silted-basin and 'Haur' soils yielding 58.6 and 37 TC/ha., respectively. The sugarcane production potential of the levee and silted-basin soils, constituting 80% of the total area, can be raised from 60 to 75% of the optimum yields. The poor yielding silted 'Haur' soils, constituting 7% of the total area, may best be reserved for growing paddy crops. The study shows that morphology and physical properties of soil greatly influence crop yield, especially that of sugarcane.

INTRODUCTION

It is well known that sugarcane needs well-drained loam soils, free of salinity and having optimum physical environments. Soil surveys can aid in

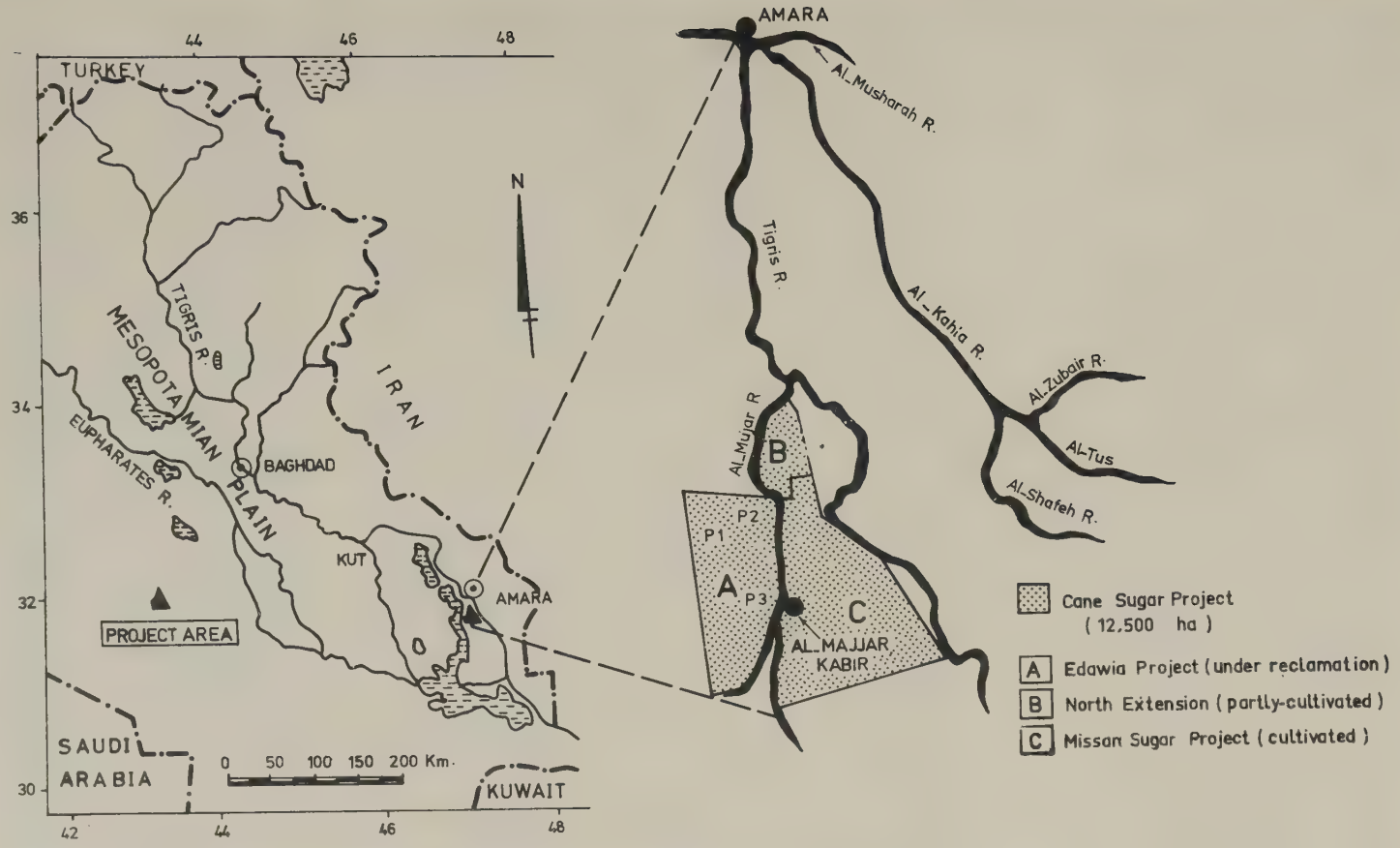

FIGURE 1. Location of Cane Sugar Project in Lower Mesopotamian Plain.

predicting the behavior and suitability of soils for growing crops and in-land use planning (Beater[6]). But very little has been reported on the nature and suitability of the Lower Mesopotamian Plain soils of Iraq in relation to their suitability for sugarcane cultivation. In certain areas, soils surveys have been done showing the extent and distribution of various soil types (Aziz and Rudainy[5]), but no attempt has been made to evaluate their suitability for growing sugarcane so that such findings could find application in other areas with comparable soil characteristics. The objective of the present study is to characterize and classify the mapped soils for evaluating their suitability for growing crops, especially sugarcane, and to evaluate the realizable and actual yields with the hope that the information obtained will be of practical value for land-use planning in Iraq and other comparable regions.

GEOGRAPHICAL SETTING

The study area is situated around the latitude of 31°.30[1] N and the longitude of 47°05'E. It forms a part of the vast Lower Mesopotamian Plain — a plain of aggradation between the Tigris and Euphrates Rivers (Fig. 1). It was formed during the Holocane and Recent times from the river sediments, derived from the north and north-eastern mountain and carried by the twin rivers.

Climatically, the area is characterized by short cool winters and long hot summers with almost no spring or autumn season. The area receives an annual rainfall of 161 mm; out of which 103 mm (62%) falls during winter (December to February) and the summers are absolutely dry. The mean annual temperature is 23.4°C with five months (November to March), having monthly temperatures below 20°C and another five months (May to September) having above 30°C. The dry period is associated with high air temperatures. The mean relative humidity is generally low in summer (48%) and high in winter (76%). The generally high relative humidity (61%) in the area may be due to its nearness to the marsh ("Haur") and the Arabian Gulf. The data show the highest pan-evaporation rate (15.8-16.7 mm per day) during summer (June to August). This may be attributed to the low relative humidity and high air temperatures during these months. The area represents a climatic type of arid (with no water surplus), megathermal (less-hot) with temperature efficiency regime normal to first megathermal (Ed, A'2a'1) (Thornthwait-System[25] as modified by Vernemmen[26]).

As a result of centuries of old cultivation, it is difficult to speculate on the natural vegetation during the earlier times. However, the dominant plants presently observed in the area are: 'Shok' *(Presopis faractum)*, 'Agul' or Camelthorn (*Alhagi maurorum*), 'Thail' (*Cynodon dactylon*), 'Showale' (*Cressa cretica*).

MATERIALS AND METHODS

A semi-detailed soil survey of a part of the project area in southern Iraq, covering an area of 5000 ha. was undertaken by using aerial photo-

interpretation technique with the objective of bringing it under sugarcane cultivation. The method adopted for mapping was as outlined in the US Soil Survey manual[20], and soils classified[21].

Based on the field observations, i.e. terrain features, including topography, natural vegetation, groundwater, drainage, salinity, and a large number of auger holes, 10 pedons, representing major physiographic units, were examined and described. For the present study, 3 widely-distributed and most typical pedons have been investigated. Their location (Fig. 1) is summarized below:

Pedon No.	Physiographic Unit
1	Silted-'Haur'
2	Silted-Basin
3	River-levee

The soil samples from different horizons were collected, processed and analyzed for various physico-chemical properties by following the standard methods (Richards[15]). The irrigation and underground water samples were also collected and analyzed for judging their suitability for irrigation purposes.

Seven, ten and fifteen fields from the silted 'Haur', silted-basin and river levee areas were selected for yield studies for the years 1975 to 1979 in relation to soil salinity. The yield was averaged for each block, then for all blocks within a field and subsequently for all fields within each physiographic unit. The average yield in metric tons cane per hecatre (TC/ha) for each physiographic unit was worked out over all crop types (plant cane and ratoons). These averages and percentages for each crop type within each physiographic unit are tabulated and discussed.

The electrical conductivity (1:1 soil water extracts) was determined for surface (0-33 cm), soil samples collected at an 80 m grid interval. The EC values were transformed to logarithms, averaged, and the antilog taken to give the average EC(1:1) for each block. Regression analysis for yield of cane on salinity was run according to Snedecor and Cochran[19].

RESULTS AND DISCUSSION

Morphology

The morphology of the soils (Table 1) suggests a stratified nature of the parent material, weak or almost no soil structures, moderate to imperfect drainage conditions and immature profile development.

TABLE 1. Salient morphological characteristics and classification of the studied pedons.

Pedon 1. Aquertic Torrifluvent: imperfectly drained, depression land (silted-Hour)

Ap (s) (0-13 cm.) Dark-Greyish-brown (10 YR 4/2, m) with remnants of

sedimentary material; a few faint mottles of darky-yellowish brown (10 YR 4/4); silty-clay; massive; firm; many, fine and medium roots; common, final shells; occasional white-ants; occasional fine tubular pores; clear smooth boundary.

C (m) (13-70 cm.) Dark-yellowish-brown (10 YR 3/4, m) with another matrix (25% by volume) of brown to dark-brown (7.5 YR 4/4, m) and common distinct reddish-brown mottles; silty-clay; weak, fine and medium sub-angular blocky (sedimentary structure); hard, firm and sticky; a few shells; rare aggrotubuls; common fine pores; clear smooth boundary.

C (ss) (70-100 cm.) Greyish brown (2.5 Y 5/2, m); common distinct mottles; silty-clay; rest as above (30-70 cm).

Pedon 2. Typic Torrifulvent (saline phase): moderately-well drained: silted-basin area.

Ap (s) (0-15 cm.) Light-brownish-grey (10 YR 6/2, d; 4/2, m); silt-loam; massive with weak, fine platy surface crust (1-2 cm); hard, friable; abundant fine roots; common salt efflorescence; clear smooth boundary

C (m) (26/32-88 cm.) Dark-brown (10 YR 3/3-m) with another matrix (30%) of brown to dark-brown (7.5 YR 4/4-m); silty-clay; moderate; coarse and medium, blocky and prismatic (sedimentary structures); firm; a few fine and occasional semi-decomposed coarse roots; clear smooth boundary.

VC (ss) (130-150+cm.) Yellowish-brown (10 YR 3/4) mottled with brown (7.5 YR 5/4); silt-loam; moderate, medium and coarse blocky and platy (sedimentary); friable; rare fine roots; occasional interpedal salt efflorescence.

N.B. The alluvium appears to have been deposited during different stages, each showing a salty layer at its surface.

Pedon 3. Typic Torrifluvent: well-drained, river-levee area.

Ap (s) (0-15 cm.) Brown (10 YR 5/3, d; 4/3, m); with a few distinct, dark-yellowish-brown) 10 YR 4/6; root mottles; silty-clay-loam; massive with weak, fine platy surface crust (3 mm); friable; many, fine and coarse roots; smooth boundary.

C (m) (40-90 cm.) Brown to dark-brown (10 YR 4/4, m) mottled with dark-yellowish-brown (10 YR 3/4, m); a few fine distinct reddish-brown mottles; silty-clay-loam; weak, medium angular blocky (sedimentary); firm; occasional lime efflorescence; occasional fine, very soft Fe-Mn concretions; common, fine-medium pores; a few, fine and coarse roots; diffuse smooth boundary.

IIC (ss) (130-160 cm.) Dark-greyish-brown (2.5 Y 4/2, m); coarse sandy-loam; massive; loose; ground water starts oozing out.

(s) surface soil; (m) subsurface soil with relatively pronounced structure; (ss) substratum/lower subsoil.

The soils are young with minimal profile development as seen from the lack of distinct horizonation. This may be the result of occasional flooding and sedimentation process. The platy structures and lithologic breaks, as observed in these soils, also support the young nature of these soils.

They are moderately well to imperfectly drained. The greyish color of the matrix within 1 m of the surface (in pedon 1), and mottled horizon (in pedon 2 and 3) support the above observations. This may be attributed to their respective topographic position, with moderately-well drained soils on river-levee and silted basin (p. 2 and 3) and imperfectly drained soils in depressions (p. 1 in silted 'Haur'). Such drainage conditions are likely to affect the soil water and air relationship for plant growth and contribute to low yields.

Most of the soils studied show distinct platy and /or prismatic (p. 2 and 3) and blocky (p. 1) structures. Such structural units are weak and unstable in water. These structural units were not distinguished from the normal soil structures developed due to pedogenesis (Al-Raw *et al*[3], Al-Taie and Stoops[4]). The developments of such structural units, especially Platy and prismatic, may probably be the result of compaction of sediments followed by development of cracks due to desiccation and swell-shrink nature of the clay minerals of such soils. The unstable nature of structural units and the recent nature of these sediments confirm our proposed hypothesis on the development of such structures, which may henceforth be termed as sedimentary soil structure.

Physico-chemical Properties

The particle-size analysis (Table 2) suggest an irregular distribution of soil separates in different pedons. The soils in silted 'Haur' depression lands (p. 1) are the heaviest with clay ranging from 54-57 per cent, followed by the soils in silted-basin and river-levee (p. 2 and 3) where the amount of clay generally varies from 30-44% with stratified coarse-textured substratum. The sand fraction in the upper 1-m soil is almost insignificant. The low per cent of sand in these soils may be attributed to the influence of parent material (Buringh[8]). The relatively coarser-textured substratum in the river-levee soils can well be explained by the nature of sediments laid by the meandering action of the river. The high sand/silt ratio showing lithologic discontinuities almost at the boundary of each horizon below almost 1 m of the surface, further support the above assertion.

The electrical conductivity (ECe) values not only vary among different members but also within each of the studied pedons. The ECe in general increases with depth except in soils developed in silted-basins (p. 2) where the surfaces also show high amount of salts. This may be due to the calcareous nature of the parent material and lack of sufficient time for the leaching of the salts. The shallow depth of underground water containing high salts as

TABLE 2. Physico-chemical properties

Hor.	Depth cm.	Soil Separates per 100 g soil Sand % (>50 μ)	Silt % (2-50μ)	Clay % (<2μ)	Tex. Class	pHs	ECe	O.M. %	$CaCO_3$ %	Gypsum %	CEC me/ 100g	ESP	Avail. P ppm	Saturation extract analysis (me/l) Ca	Mg	Na	Total Cations	Cl	SO_4	HCO_3	Total Anions	SAR
Pedon 1. Aquertic Torrifluvent (in Silted 'Haur')																						
Ap(s)	0-13	3	43	54	Sic	8.1	2.8	1.32	27.1	0.03	30.0	7.7	3.5	18	5	16.0	40.0	12	25	1.2	38	4.6
C(m)	13-70	1	42	57	Sic	8.1	4.2	0.62	23.6	0.16	30.4	99.2	3.2	23	20	28.5	72.1	27	41	1.4	69	6.0
C(ss)	0-100	2	43	55	Sic	8.2	5.0	1.05	19.4	Nil	35.4	9.8	8.0	28	14	31.8	73.8	39	30	1.2	70	6.9
Pedon 2. Typic Torrifluvent — saline phase (in Silted-Basin)																						
Ap(s)	0-15	7	64	29	Sil	8.1	10.9	1.46	25.4	0.16	22.5	11.6	11.5	66	36	58	160	114	40	1.6	155	8.1
C(m)	26/32-88	1	55	44	Sic	8.1	8.3	0.56	25.9	0.09	24.4	12.4	3.8	32	36	50.5	118	78	37	1.2	116	8.6
VC(ss)	130-150+	10	65	25	Sil	8.05	7.6	0.41	26.6	0.61	20.6	13.3	2.4	30	34	49.4	113	64.5	45	1.0	111	8.8
Pedon 3. Typic Torrifluvent (in Levee)																						
Ap(s)	0-15	7	62	31	Sicl	7.8	3.5	2.13	25.4	0.08	24.8	5.2	5.5	26.0	14	12.2	52.2	33.0	1.6	1.4	49	2.7
C(m)	40-90	2	66	32	Sicl	7.7	12.0	0.67	26.7	0.18	24.3	11.9	1.5	62.0	52	67.5	181	132	40	1.0	173	8.9
IIC(ss)	130-160	74	20	6	Sl	7.8	24.9	0.28	26.9	0.18	10.2	20.6	2.0	70.0	132	168	370	315	44	1.2	360	16.7

compared with that of the river water (Table 3) may be an important source of salts in these soils (Abtahi[2]). The high ECe values at the surfaces in pedon 2 may be attributed to the capillary rise of ground water bringing salts along, which on evaporation are left at the surfaces.

TABLE 3. Quality of underground and river irrigation waters.

Sample	Location	EC x 10^6	ph	Cations and Anions (Meg/L)							
				Na	Ca	Mg	Ca:Mg	Cl	SO_4	HCO_3	CO_3
Underground water	P.9	12200	7.1	51.6	2.4	6.8	0.35	66.3	—	0.7	nil
Underground water	A-125	14700	7.5	95.0	3.1	6.6	0.47	94.8	—	0.7	nil
River water	(Al-Mujar)	860	7.5	2.5	3.5	3.0	1.18	—	—	—	—

A perusal of the data (Table 3) show that the EC values of the underground waters are very high (12,000 to 14,700 microm hos/cm) as compared with the salt content of the irrigation water (from Al-Mujar River) which is low (850 microm hos/cm). The Ca:Mg ratio of 1 : 2 in the river water drops to about 0.4 in the ground water suggesting the removal of Ca either as insoluble carbonates or slightly-soluble gypsum. The inadequate natural drainage coupled with heavy irrigation might have resulted in high salinity in the underground water and high subsoil water table. As a consequence of the high evapotranspiration, the salts in the underground water rise and accumulate in the top soil. The fallowing of these soils and the dust which envelopes the atmosphere for some time during the summer period may be responsible for the accumulation of salts at the surfaces. The only way of leaching and maintaining a water-salt equilibrium favorable for sustained productivity is to control the rise of the subsoil water table and to gradually wash out the excessive salts from the root zone. This can be achieved through artificial drainage.

The high salt at the surfaces might limit the growth of some crops like sugarcane, maize, cotton, wheat, etc. Sugarcane has been reported by some workers (Mehrad[14], Robinson and Worker[17]) to be salt-sensitive while others (Abrol *et al*[1], Bernstein *et al*[7], Richards[15]), believe it to be a salt-tolerant crop. Robinson and Worker[17] demonstrated a 50% reduction in the yield of sugarcane (NCo 310) at an ECe value of 4.2. Similar results were also reported by Mahrad[14]. However, Bernstein *et al*[7], and Dev and Bajwa[9] observed a 50% reduction in the yield of sugarcane only at an ECe of 8-10 mm hos/cm. The difference in the salt tolerance of sugarcane, as observed by different workers, may be attributed to the differences in physical properties of soils, especially soil texture and permeability.

Bulk density is greater than 1.4 g/cm^3 in fine textured soil, and greater than 1.65 g/cm^3 in coarse textured soils, are known to restrict root growth (Juang and Ushara[13]). A perusal of the data on the physical analysis of these

soils (Table 4) reveals that the bulk density of the surface soil varies from 1.36 to 1.38 g/cm^3, in all the three soils, and the precentage of non-capillary pores (greater than 0.009 mm diameter) varies from 16.6 silted-'Haur' to 27.3 in the silted basin soils, indicating favorable conditions for the growth of plant roots, exchange of gases and percolation of water through this layer.

The permeability of the surface soil, has been observed to vary from moderately-slow to slow (19.2 cm/day in silted-'Haur' to 4.0 cm/day in silted basin soils) and the initial infiltration rates from 0.9 cm/hr in silted-basin to 1.6 cm/hr in silted-'Haur' soil, which decreased to 0.2 cm/hr, after three hours of inflow. The slow permeability and slow infiltration rates could be attributed to the presence of surface crust (silted-basin soils), high percentage of calcium carbonate which, being relatively insoluble in water, is likely to clog the water conducting pores and to the montmorillonitic type of clays.

The bulk density of subsurface soil varies from 1.5 g/cm^3 in silted-'Haur' and silted-basin to 1.6 g/cm^3 in river-levee soils. The relatively high bulk densities of subsurface soils might have been caused by the orientation of silt and clay sediments during deposition followed by compaction due to sediments load as is evident from the platy (sedimentary) structures observed in these soils. The young nature of the soil with little pedogenic activity and absence of well-developed soil structure supports these inferences.

The relatively low percentage of non-capillary pores, varying from 4.3 in silted-Haur to 8.2 in silted-basin soils, is likely to reduce the exchange of gases, flow of water through soil, and limit the growth of roots in this layer. The use of heavy machinery in sugarcane cultivation may also be responsible for aggravating the problem of soil compaction (Young[28]). The field studies conducted in the area planted to sugarcane show that most of the roots were confined to the upper 20 cm of the surface, most probably due to the limited availability of oxygen, which weakened the roots, and the high bulk density which by thickening the roots and encouraging the development of only rudimentary laterals, reduces their capability to penetrate the subsurface soil of relatively high bulk density. The heavy irrigation doses, each of 12-15 cm, generally applied to meet the water and leaching requirements, often remain ponded on the soil surface for a considerable time. This may be expected from the very slow saturated permeability values of these soils which vary from 0.2 cm/day (in river-levee-soils) to 2.5 cm/day (in silted-'Haur' soils).

The apparent permeability of the whole soil profile varies from 2.73 to 0.2 cm/day, with maximum in the silted-'Haur' and minimum in the river-levee soils. Bonnan[10] reported a similar magnitude of the permeability coefficient for such soils. The very slow apparent permeability of these soils is likely to limit the removal of salts by leaching. These soils, if they should remain wet for a considerable time, are likely to build up a perched water-table, which would stimulate the recycling of salts due to the existence of a zone of capillary fringe, and relatively high rates of upward-flow of water due to high unsaturated hydraulic conductivities of fine-textured soils.

TABLE 4. Physical properties of the studied pedons

Horizon	Depth cm	Permeability			Infiltration			Bulk Density (g/cm^3)	Pore Volume 0.009 mm. dia. %	Water Storage Capacity (1/3-15 bar) per 100 cm (cm)
		Cm/day	Classification	Apparent for whole Profile (cm/day)	Initial (cm/hr)	Final (cm/hr)	Commulative (cm/hr)			
				Pedon 1. Aquertic Torrifluvent (in Silted-Haur)						
Ap (s)	0-13	19.2	MS	2.7	1.6	0.2	1.5	1.36	16.6	12.3
C(m)	13-70	2.5	VS	—	—	—	—	1.52	4.3	—
				Pedon 2. Typic Torrifluvent (Saline Phase) (in Silted-Basin)						
Ap (s)	0-15	4.0	S	0.8	0.8	0.2	0.9	1.37	27.3	15.9
C (m)	26/32-88	0.4	VS	—	—	—	—	1.52	8.2	—
VC (ss)	130-150+	7.1	MS	—	—	—	—	1.45	17.5	—
				Pedon 3. Typic Torrifluvent (in River-Levee)						
AP (s)	0-15	7.3	S	0.2	1.2	0.2	1.3	1.38	23.4	15.3
C (m)	40-90	0.2	VS	—	—	—	—	1.58	7.5	—
IIC (ss)	132-160	66.2	M	—	—	—	—	1.46	27.0	—

**M = moderate; S = slow; V = very*

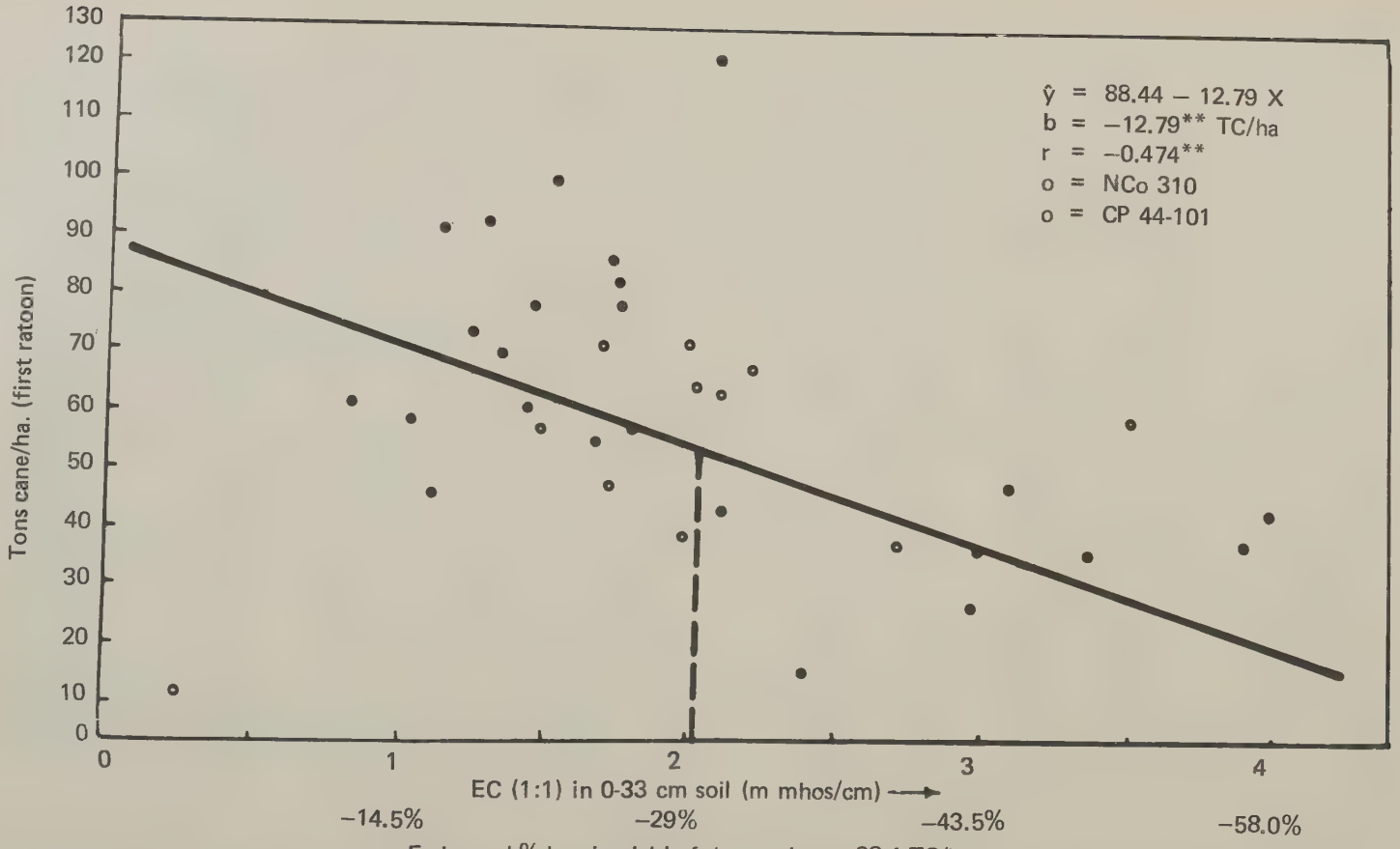

FIGURE 2. Linear regression of cane yield (TC/ha) as a function of increasing salinity in Levee Soils.

A critical study of the soils used by different workers showed a significant variation in texture from sandy-loam (Bernstein *et al*[7], Dev and Bajwa[9]) to silty-clay (Mehrad[14]) which has been reported to have different permeability. (Bonnan[10]). The soils studied in the present investigation are in general silty-clay in the upper 1 m (having silt and clay content of more than 95%), and as such are likely to show sensitivity to salts at very low EC values (Fig. 2). The data (Fig. 2) indicate a negative regression coefficient (b) = 12.8 TC/ha. drop for each unit increases in EC (1:1) in the case of levee soils.

On extrapolation, an estimated high yield of 88.4 TC/ha. can be obtained at a theoretical EC (1:1) level of zero; at an EC of 1.0, the estimated yield will be 71 TC/ha. The reduction in yield works out to be 14.5% for each unit increase in EC (1:1). This implies a 25% reduction in cane yield of NCo 310 at an EC (1:1) of 1.8 (ECe 2.8) and 50% at ECe of 5.5 mmhos/cm. Studies conducted on comparable soils in Iran (Sund and Clements[23]) showed a 25% reduction in cane tonnage at an ECe of 3.5 m mhos/cm. Accordingly, an ECe value of about 4 m mhos is the threshold, above which yields of most sugarcane varieties are adversely affected.

The significant negative correlation ($r = 0.474$)** at 0.01 probability, showing marked reduction in yield even at low salinity levels, supports our inferences on the sensitivity of those massive, clayey soils towards salinity. It seems to be apparent in the levee soils with high moisture content and very slow apparent permeability. The high summer temperature (34°C or more), high evaporative demand (±16 mm/day) and development of shallow (<1m) groundwater-table with flooding and excessive irrigation may facilitate accumulation of salts. As such these areas may need internal drainage network before bringing under sugarcane cultivation.

The high amount of carbonates of calcium and magnesium (Table 2), or of both, throughout the profile and in all the soils studied indicates the influence of calcareous alluvium on which these soils have developed, and the limiting climate and time in the leaching of salts and development of these soils (Sehgal *et al*[18]). These observations also find support from the classic work of Jenny[12]. Such high amounts of lime may limit the growth of some of the lime-sensitive crops, like citrus, potatoes, etc.

The soils in general are low to medium in organic matter, especially in the surface horizons. Its amount, however, decreases irregularly with depth supporting the stratified nature of the parent material. The relatively high content of organic matter at the surface of these soils cannot be explained under the prevailing arid and megathermal climatic and desertic vegetation conditions, it may be the function of frequency of flooding and the fluviatile nature of sediments.

The data (Table 2) suggest moderate values (20-35 me/100 g) of cation exchange capacity in these soils. The exchange capacity on clays works out to be 48-80 me/100 g, suggesting the presence of illite and swelling type of clay mineral, like montmorillonite (Al-Ta, *et al*[4], Buringh[8], Yahia[27]). Because

of the low amount of organic matter in these soils, the exchange sites seem to be controlled predominantly by the clay content. The exchange complex is dominated by calcium and magnesium, followed by sodium. The amount of exchangeable sodium shows an increasing trend with depth which may be due to the influence of residual sodium carbonate in the groundwater.

The substrata have layers of medium-textured soil, which may provide favorable conditions for drainage, reclamation and lowering of water-table in these soils, and would also help in reducing the upward movement of salts once these soils are leached and water-table maintained below these layers.

The water storage capacity per meter depth of these soils, determined by the volume of capillary pores in different layers of the soil profile, and quantified as a difference in the amount of water held between 1/3 and 15-bar tensions varies from 12.3 to 15.9 cm with maximum in the silted-basin and minimum in the silted-Haur soils. It can be classified as medium and is therefore, suitable for the growth of most of the crops.

Soil Suitability

For practical land-use evaluation, several systems have been proposed for use in different regions (Hougton[11]). But none of these systems were based on general parameters that could be effectively applied over a large area. Efforts in this direction have recently been made (Ricquier *et al*[16]). Following Storie's[22] classic ideas, Sys and Verheye[24] proposed the following Capability Index (Cs) for crop production in the arid and semi-arid regions: Cs = A.B.C.D.E.F.G.H.I. The system is based on nine properties (soil texture, calcium carbonate, gypsum, salinity, sodium-saturation, drainage, soil depth, epipedon and weathering stage as expressed by the profile development). Although it covers most of the important properties of the arid soils, some physical characteristics of great significance to plant growth have not been considered. Physical conditions either occurring naturally and/or brought about by using heavy machinery, heavy irrigation, etc., affect the supply of air, water and nutrients for plant growth. The desired physical conditions may be altered to some extent but not to the extent as its fertility. Juang and Ushara[13] reported a sharp reduction in nutrient uptake between bulk densities of 1.4 and 1.69 g/cm^3. In view of these considerations, the criteria, proposed by Sys and Verheye[24] were slightly modified and the product of the following nine parameters used for evaluating the capability index (Cs) of the studied soils for growing most important crops of the region, especially sugarcane:

$$Cs = A.B.C.D.E.F.G.H.I.$$

Where A through I are the indices related to the soil texture (A), $CaCO_3$ status (B), gypsum status (C), salinity status (D), sodium saturation (E), epipedon development (F), drainage (G), water storage capacity (H), and soil aeration capacity (I).

Using the above criteria and the index values (Sys and Verheye[24]),

the capability index for major crops of the area, including sugarcane, has been calculated for the studied soils. According to the values of indices, the suitability classes have been worked out (Table 5).

The capability classes given in Table 5-b show that not all the soils are equally suitable for growing any of the crops, including sugarcane. Pedon 3 (Typic Torrifluvent) in river-levee area works out to be relatively the most suitable and pedon 1 (a silted-'Haur' member) the least suited to cane and wheat. For growing sugarcane, the data (Table 5) suggest that the river-levee soils (pedon 3) are the best (moderately-suitable) followed by the silted-basin soils (pedon 2), and silted-'Haur' (pedon 1) soils are only slightly-suitable.

The maximum yields of sugarcane on moderately-suitable soils are likely to be between 50 to 75% of the optimum as is evident in Table 6. The data further suggest that at present most of the soils studied are comparatively better suited for growing rice with suitability class ranging from II to III followed by wheat and sugarcane (Table 5).

In order to confirm the observed suitability indices of the soils studied for sugarcane plantation, the yield data of the area already under plantation at the Misan Sugarcane Farm (3,000 ha.) was analyzed and average yields reported in Table 7. The data suggest that the overall observed yields (of the reclaimed area) in levee soils are the highest (74.6 TC/ha) followed by silted-basin soils (58.7 TC/ha); the silted-Haur soils give the lowest (37 TC/ha) yields.

The data further show that the yields in levee soils, although relatively the highest, are only moderate when compared with the yields on comparable soils in Iran (120 TC/ha) (Sund and Clements[23]) and in Somalia (92 TC/ha) suggesting that these soils are only moderately suitable for sugarcane cultivation. Furthermore, theoretical yield based upon sun radiation, evapotranspiration and canopy factor works out to 215.8 TC/ha. After applying a ratooning factor of 0.9 and management factor of 0.7, a realizable (optimum) yield of 135.9 TC/ha may be obtained. The average yields in some blocks of the cultivated area ranged from 121 up to 140 TC/ha, confirming the estimated maximum realizable yield.

Applying the average capability indices of the suitability classes, the theoritical and realizable yields show a marked decline from the calculated yield of 215.8 TC/ha (Table 6). This decrease in yield is comparable to the actual yield averages (Table 6). However, the actual: realizable yield for the three broad soil-physiographic units is 88; 116 and 74%, respectively. The actual yields represents 57.5, 45.2 and 28.4% of the maximum realizable yield for these three soil units, respectively. This confirms that the derived capability indices are applicable to the soils of the project area, and that their actual yields are below the potential cane yields.

Further it also supports our observations that the actual yields of sugarcane in the levee soils are only 50 to 75% of the optimum. The leaching and installation of proper drainage networks as well as continuous cultivation under

TABLE 5 (a). Capability ratings, indices (Ca) and suitability classes of the soils studied for various crops

Soil Capability Rating for:	Pedon-1 Aquertic Torrifluvent			Pedon-2 Typic Torrifluvent (saline phase)			Pedon-3 Typic Torrifluvent		
	Sugar-cane	Wheat	Rice	Sugar-cane	Wheat	Rice	Sugar-cane	Wheat	Rice
A. Soil Texture	100	100	100	100	100	100	105	105	100
B. Calcium Carbonate Status	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
C. Gypsum Status	1.0	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.0
D. Salinity Status	0.9	0.95	1.0	0.7	0.8	0.8	0.8	0.90	0.90
E. Sodium Saturation (ESP)	0.95	0.95	0.95	0.9	0.9	0.95	0.95	0.95	0.95
F. Epipedon	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1
G. Drainage	0.75	0.75	0.95	0.80	0.80	0.90	0.85	0.85	0.90
H. Water Storage Capacity	0.80	0.85	0.95	0.9	0.95	1.0	0.9	0.95	1.0
I. Soil Aeration Capacity	0.8	0.8	0.90	0.95	0.95	0.9	0.95	0.95	0.9
Overall Cap. Index (Ca)	41	46	77	47	57	68	64	76	76
Soil Suitability Classes	(IV)	(III)	(II)	(IV)	(IV)	(III)	(III)	(II)	(II)

TABLE 5 (b). Capability indices (Cs) of the soils studied for various crops

Pedon No. and Soil Group	Capability Index (Cs) & Suitability Class for Sugarcane	Wheat	Rice
1. Aquertic Torrifluvent (in Silted-'Haur')	41 (IV)	46 (III)	77 (II)
2. Typic Torrifluvent (saline phase (in Silted-Basin)	42 (IV)	57 (IV)	68 (III)
3. Typic Torrifluvent (in River-Levee)	64 (III)	76 (II)	76 (II)

Soil Suitability Class

Class I.	*Very-Suitable:*	*Cs > 90; yields very high*
Class II.	*Suitable:*	*Cs 75 o 90; expected yields 75% of the optimum yield*
Class III.	*Moderately-suitable:*	*Cs 50 to 75; expected yields are moderate*
Class IV.	*Slightly-suitable:*	*Cs 25 to 50; low yields; soils are used only if no alternative land is available*
Class V.	*Unsuitable:*	*Cs < 25; cultivation cannot be recommended under management*

effective management may enhance the yield potential of the levee and silted-basin soils from 50 to 75% of the optimum (realizable) yields.

The data (Table 8) further show that cane yield increased by 100 to 153 and 132% by progressive ratooning in case of levee and silted-basin soils respectively. On the contrary, a yield decrease (from 100 to 71%) was

TABLE 6. Average[1], theoretical[2], realizable[3] (optimum) and actual yield under different suitability classes and their capability indices (Cs)

Suitability Class	Cs %	Yield Average (TC/ha) Theoretical	Realizable	Actual	% Actual: Realizable
I	90	204.9	129.8	–	–
II	75-90	177.9	112.1	–	–
III	50-74	134.5	84.6	74.6	88.2
IV	25-49	80.4	50.6	{ 58.7	{115.9
				{ 37.0	{ 74.0

1. *Yield average for the capability index (Cs)*
2. *Calculated from high yield of 215.8 TC/ha as an outcome of evapotranspiration of 2,600 mm/year and a canopy factor of 0.83*
3. *After applying ratooning factor of 0.9 and management factor of 0.7 on the theoretical average within each suitability class*
4. *Silted - basin*
5. *Silted 'Haur'*

TABLE 7. Distribution of area (estimated) (%) and average yield over all crop types under each physiographic unit during 1975-1979

Physic Unit	Area in hectares (percent)				
Area	River-Levee	Silted-Basin	Silted-'Haur'	Others	Total
A*	1315	2865	820		5000
(%)	(26.3)	(57.3)	(16.4)		(100)
B*	130	527	–	343	1000
(%)	(13.0)	(52.7)	–	(2.8)	(100)
C*	2044	3844	362		6250
(%)	(32.7)	(61.5)	(5.8)		(100)
Total	3489	7236	1182	1403	12250
(%)	(28.5)	(59.1)	(9.6)	(11.4)	(100)
Yield (TC/ha)	74.6	58.7	36.96		
	(100)	(78.6)	(49.5)		

**See figure 1*

observed in case of silted-'Haur' soils. This may suggest that continuous cropping helps in improving the soil conditions in the levee-and silted-basin soils. However, the same is not true of the silted-'Haur' soils which show a decline in yield after the first ratoon. The data further show that average cane yields for the silted-'Haur' soils are only 47% of those observed in levee soils. As such, these soils may best be exploited for growing paddy for which they have been found to be better suited.

TABLE 8. Average yield production (TC/ha) and % per soil group and crop type during 1975-1979

Soil Group / Crop Type	Levee	Basin	'Haur'	Average
Plant Crop	53.0	48.9	33.5	45.13
(%)	(100)	(100)	(100)	(100)
Ratoon 1	53.3	50.8	40.4	48.23
(%)	(101)	(104)	(121)	(107)
Ratoon 2	66.0	55.9	23.1	48.33
(%)	(124)	(114)	(69)	(107)
Ratoon 3	81.9	64.9	23.7	56.56
(%)	(153)	(133)	(71)	(125)
Average	63.4	55.1	30.2	–
(%)	(100)	(87)	(48)	–
S.E. +	6.62	3.58	4.16	– –

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LOS SUELOS DE PLANICIE BAJA DE MESOPOTAMIA Y SU ADAPTABILIDAD PARA LA SIEMBRA DE CAÑA DE AZUCAR

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RESUMEN

Se investigaron tres pedones típicos y ampliamente distribuidos en la Planicie Baja de Mesopotamia (Irak Maridional) en cuanto a sus propiedades morfologicas y fisico-químicas para evaluar su adaptabilidad para varios cultivos, especialmente caña de azúcar, y para extrapolar los rendimientos de caña realizables y actuales. Los suelos (Aquertic y Typic Torrifluvents) muestran estratificacion de sedimentos con estructuras laminadas (sedimentaria) y drenaje imperfecto. Son altamente calcareos, franco-arcillo- limosos a franco arcillosos, ligeramente a moderadamente salinos y se agristan al secar. Mientras que los suelos superficiales tienen favorables condiciones físicas para sembrar la mayoria de las cosechas los subsuelos tienen propiedades fisicas indeseables. Se estableció una significativa correlación negativa entre tonelaje de caña y C.E. (1:1) de manera que una C.E. de 2.8 parece ser crítica al mermar los rendimientos de caña por 25%. Utilizando el aproche parametrico, los suelos de

dique se encontraron moderadamente adaptables para la siembra de caña de azucar seguidos por los limosos de valle; los suelos limosos de "Haur" son los menos adaptables. El retonamiento progresivo mostro un aumento actual promedio de 45 a 56 TC/ha. Sin embargo, este aumento fue mas significativo en suelos de dique (74.6 TC/ha) que en suelos limosos de valle y suelos "Haur" produciendo 58.6 y 37 TC/ha, respectivamente. El potencial de producción de caña de azúcar de los suelos de dique y limosos de valle, que constituyen 80% del area total, se puede aumentar, desde 50 hasta 75% de los rendimientos óptimos. Los suelos limosos "Haur" de pobre rendimiento, que constituyen 7% del área total, deben mejor ser reservados para el cultivo de arroz. El estudio muestra que las propiedades morfologicas y físicas del suelo influyen grandimente sobre los rendimientos de los cultivos, especialmente los de caña de azúcar.

COMPARISON OF SIX TISSUES FOR DIAGNOSIS OF SUGARCANE MINERAL NUTRIENT STATUS

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ABSTRACT

The choice of a diagnostic tissue for mineral nutrient analysis of sugarcane *(Saccharum spp.*, a complex trispecies hybrid) varies throughout the world. The objective of this study was to compare six diagnostic tissues which are used in various sugarcane growing countries and to select the best one in terms of sensitivity, accuracy, and applicability. The six tissues were: (1) the top visible dewlap (TVD) leaf blade, (2) the TVD leaf lamina, (3) the middle portion of the TVD leaf blade, (4) the middle portions of the elongating leaf laminae (from leaves +3 to +6), (5) the elongating leaf sheaths (from leaves +3 to +6), and (6) the whole above-ground plant. Samples were obtained at 5 months of age from four commercial first ratoon cane fields in the Everglades Agricultural Area. Each field was divided into four sites. Six duplicates tissue samples were randomly collected from each site. The experimental design was a randomized complete block with blocks consisting of fields and sites nested within fields. Tissue samples were analyzed for N, P, K, Ca, Mg, Mn, Cu, and Zn. Sugar yield estimation was made prior to harvest. Data from the TVD leaf blade, the TVD leaf lamina. and the middle portion of the TVD leaf blade resulted in relatively high correlation coefficients between cane yield and nutrient concentrations. All tissues were well correlated with the whole plant nutrient status. Nutrient concentrations were not statistically different between the whole TVD leaf blade and the middle portion of the TVD leaf blade. The practice of sub-sampling the middle portion from the whole leaf appeared to be unnecessary. The middle portion of the TVD leaf blade resulted in large coefficients of variation among replicates. Selection of the TVD leaf, with or without its midrib, insured precision of tissue analysis by offering low variability among replicates. The TVD leaf is well defined and easily accessible, making it the tissue of choice for estimating the nutrient status of sugarcane.

[1] *Florida Agricultural Experiment Stations Journal Series No. 1904.*

INTRODUCTION

Tissue diagnostic methods have been extensively used in determining the mineral nutritional status of sugarcane *(Saccharum spp.,* a complex trispecies hybrid). Although the same theoretical basis underlies all diagnostic methods, the actual practice varies from the choice of diagnostic tissues to the interpretation of the results (Evans[5]).

The top visible dewlap (TVD) leaf blade of sugarcane was selected for diagnostic purposes in Mauritius (Halais[11]). The whole TVD leaf blade sample was used in Jamaica (Innes[12]), and South Africa (Beaufils and Summer[3]). Clements[4] in Hawaii selected the elongating-blades and sheaths from leaves +3 to +6. Leaf-punched samples were taken from the elongating blades for N analysis and the corresponding sheaths were sampled for determiation of P, K, Ca, Mg, and plant moisture.

Due to the gradient in nutrient concentrations along the whole leaf blade, the middle portion of the blade has been suggested to be the most reliable region for sampling (Farquhar and Lee[6]). Accordingly, the 20-cm middle portion of the TVD blade was used in Australia but only a 10 cm portion was taken in Mauritius (Halais[11]). A 20 cm middle portion of the elongating blade was selected in India (Laksmikantham, *et al.*[13]), the middle one-third of the elongating blade in Mexico (Portales[15]), and Texas (Thomas and Oerther[19]), the middle portions of blades +3 to +4 in Brazil (Malavolta[14]), and a 5 to 6 cm middle portion of leaf blades in Puerto Rico. The midrib is usually discarded after collecting leaf blade samples except in Puerto Rico (Samuels[16]).

Despite such diversity in sampling techniques, few comparative investigations have been made to assess the accuracy of each method under similar conditions. Samuels *et al.*[17] compared the different leaf sampling methods used in British Guiana (Guyana), Hawaii, Jamaica, Mauritius, and Puerto Rico. They noted that regardless of the country, method, or cane variety, the optimum nutrient values were similar after appropriate adjustments had been made.

Since tissue analysis is widely used, the standardization and refinement of the technique is important. The objective of this investigation was to compare six diagnostic tissues and select the best one in terms of sensitivity, accuracy, and applicability.

MATERIALS AND METHODS

Four commercial cane fields were randomly selected in the Everglades Agricultural Area. The soil was classified as a Pahokee muck (Lithic Medisaprist). All fields were first ratoons of the most popular commercial cultivar in Florida, 'CP 63-588'.

Six diagnostic tissues were selected for study:

1. Top visible dewlap (TVD) leaf blade with its midrib.
2. Top visible dewlap leaf blade lamina without its midrib.

3. Middle portion (10 cm) of the TVD leaf blade with its midrib.
4. Middle portions (20 cm) of the elongating leaf blade laminae (from leaves +3 to +6).
5. Elongating leaf sheath (from leaves +3 to +6).
6. Whole above-ground plant.

Each cane field was equally divided into four sites. A 15 m section of a row was measured off in the middle of each field site. Five samples of each diagnostic tissue were randomly collected on each side of the measured center row. Each of the five samples were then composited. The sites were then resampled in the same manner for duplication. This procedure was followed to obtain all six diagnostic tissues. Thus the experiment consisted of four fields x four sites in each field x six tissues x two replications. The experimental design was a randomized complete block with blocks consisting of fields and sites nested within fields. Sampling was confined to the period from 8 to 11 a.m. Cane plants in all fields were of the same height and above 5-months old at the time of sampling.

Tissue samples were dried at 70°C and ground to 20 mesh in a stainless steel Wiley mill. All analysis were run in duplicate and averaged. Total N was determined by a standard semi-micro Kjeldahl method. The samples were also wet-ashed using a nitric acid-perchloric acid procedure (Barton[2], Gee and Deitz[8]) and for K, Ca, Mg, Mn, Cu, and Zn by atomic absorption spectroscopy. Soil samples were taken at the same time as the tissue samples. Ten soil cores, taken to a depth of 30 cm, were composited into one representative sample. Soil analysis was made by the methods of Thomas[18]. Soil pH was determined using a 1:2 soil: water mixture. Soil P was extracted with distilled water; K, Ca, and Mg were extracted with 0.5 N acetic acid.

A stalk count was made at the time of sampling. Millable stalks were counted 3 months later. Prior to harvest, 10 consecutive stalks were cut from the designated 15 m plant row. Stalk samples were weighed and crushed in a 3-roller sample mill. Cane juice was analyzed for Brix and sucrose and the theoretical yield of 96° sucrose in cane was calculated using a modified Winter-Carp-Geerligs formula (Arceneaux[1]). The data were submitted to analysis of variance. Means were compared by Duncan's multiple range test. Tests of the sensitivity of diagnostic tissues were conducted by comparing simple correlation coefficients between nutrient concentrations of diagnostic tissue samples and sugar yields of the corresponding cane fields. Coefficients of variation were computed to compare the precision of the diagnostic tissues.

RESULTS AND DISCUSSION

Comparison of Nutrient Concentration Among Six Tissues

Significant differences in nutrient concentrations were found among tissues for N, P, K, Ca, Mg, Mn, and Cu but not for Zn (Table 1). The inclusion of the midrib with the TVD leaf blade lamina significantly decreased N, P, and Mg concentrations, increased K and did not affect Ca, Mn, Cu, and Zn. Similar trends for N, P, and K as affected by the midrib were reported by Samuels *et al.*[17]

TABLE 1. Mean nutrient values for six sugarcane tissues.

Tissues	Plant tissue nutrients							
	N	P	K	Ca	Mg	Mn	Cu	Zn
	%					ppm		
TVD leaf blade	1.58 c[+]	0.20 b	1.88 c	0.24 bc	0.33 e	44 b	10 bc	22 a
TVD leaf lamina	2.24 a	0.25 a	1.43 d	0.28 b	0.38 bc	41 b	10 bc	26 a
Middle of TVD leaf blade	2.08 b	0.24 a	1.45 d	0.27 bc	0.40 b	40 b	7 c	28 a
Middle of elongating leaf lamina	2.32 a	0.26 a	1.24 d	0.44 a	0.46 a	54 a	7 c	27 a
Elongating leaf sheath	0.58 e	0.10 d	2.85 a	0.17 d	0.36 cd	45 b	24 a	28 a
Whole above-ground plant	1.12 d	0.16c	2.52 b	0.22c	0.34 de	42 b	16 b	35 a

[+] In a given column, means followed by a common letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

Despite the reported gradient in nutrient contents along the leaf blade (Farquhar and Lee[6]), no statistical differences between the TVD whole-leaf lamina and the middle portions of the elongating leaf laminae for N, P, K, Cu, and Zn were recorded. Likewise, the TVD whole-leaf lamina was not different from the middle portion of the TVD leaf blade for P, K, Ca, Mg, Mn, Cu, and Zn. This implies that sub-sampling only the middle portion from the leaf blade will not significantly affect the results.

Each nutrient had a characteristic trend among the six tissues. The concentrations of N, P, and Ca among the six tissues were found in the following order: the middle portion of the elongating leaf blade lamina > the TVD leaf blade lamina > the middle of TVD leaf blade > the whole TVD leaf blade > the whole plant > the elongating leaf sheath. Potassium followed exactly the reverse trend. This emphasized the fact that K strongly competes for absorption and inhibits the accumulation of N, P, and Ca in each plant part. The highest N and P concentrations were found in the leaf lamina indicating a peak of foliar metabolic activity. Potassium concentrations, on the other hand, accumulated in the conducting tissues such as leaf sheath and midrib. Since each tissue had a characteristic nutrient content, the results of tissue analysis were comparable only on the basis of the same tissue. Indiscriminate utilization of optimum nutrient values from different countries using different tissues may lead to erroneous interpretation of results.

Selection of an Indicator Tissue to Assess the Whole Plant Nutrient Status

It is assumed that a tissue which is best correlated with the whole plant nutrient status will be the most representative part of that plant. Thus an attempt was made to correlate the nutrient concentrations of five specific diagnostic tissues to that of the whole palnt. This study indicated high correlation between the whole plant and other specific tissues for all nutrients except K and Zn (Table 2). The results were poor for K and inconsistent for Zn. The TVD leaf blade lamina gave the highest correlation coefficients with the whole plant for N. Furthermore, it resulted in correlation coefficients that were as high or higher than other tissues for P, K, Ca, Mg, Mn, Cu, and Zn. The middle portions of TVD leaf blade and elongating leaf blade laminae had low correlations with the whole plant for all nutrients except P and Mn. The TVD leaf blade, and the leaf sheath yielded equally high correlation coefficients for all nutrients. The overall trend indicated that the TVD leaf lamina, the whole TVD leaf blade, and the leaf sheath were satisfactory tissues for evaluating the whole plant nutrient status.

Test of Sensitivity of Diagnosis

Assuming that the best diagnostic tissue has the greatest sensitivity in reflecting yield-nutrient concentration relationships, tissue and soil analyses were carefully examined with respect to sugarcane and sugar yield in each field. Considerable differences in yield were found among fields, the lowest and highest being 37 and 125 metric tons cane/ha (TCH), respectively. There were no significant differences in Brix, sucrose in the juice or in purity among fields. Millable

TABLE 2. Correlation coefficients (r) of the whole plant and five specific sugarcane tissues for each nutrient.

Plant tissue	Plant tissue nutrient							
	N	P	K	Ca	Mg	Cu	Mn	Zn
	r							
TVD leaf blade	0.41*	0.58**	0.16	0.79**	0.84**	0.72**	0.88*	0.24
TVD leaf lamina	0.68**	0.67**	0.22	0.74**	0.81	0.62**	0.85**	0.39*
Middle of TVD leaf blade	0.13	0.71**	0.09	0.61**	0.77**	0.62**	0.86**	-0.29
Middle of elongating leaf lamina	0.27	0.66**	0.19	0.68**	0.73**	0.62**	0.82**	-0.38*
Elongating leaf sheath	0.43*	0.64**	0.30	0.76**	0.80**	0.73**	0.74**	0.44**

** * *Significant at 1% level, and 5% level, respectively.*

stalk population was significantly lower in the lowest yielding field than in the other fields.

In an effort to correlate plant nutrients concentrations to crop yield, N was not considered to be a limiting factor on muck soil. In most observations, N is excessive with respect to P, K, Ca, and Cu (Gascho and Wali[7]). Their interrelationships were related to TCH. Soil tests indicated low P status for all fields. Diagnostic tissues showed that P was low with respect to N or that low P was associated with high K concentration in the low yielding fields. In the high-yielding fields, N, P, K, Ca, and Mg appeared to be in balance. The micronutrient concentrations in the tissue and analysis were affected by soil pH. Tissue Mn concentrations were negatively correlated with soil pH in all fields. However, tissue Cu concentrations were not related to soil pH in the lowest yielding field. Even though the soil pH was low enough to cause high Cu availability, the tissue Cu concentrations were found to be below the critical level.

Since interactions existed among nutrients, the concentration of a particular nutrient may not have been indicative of the real plant nutrient status. Nutrient ratios take into account the interactive factors which can be directly related to crop-yield response. For example, the N/P ratios of tissue were negatively correlated with TCH 9(Table 3). This implies that high N levels with relatively low P can result in reduced sugar yields. Analysis of the TVD leaf blade lamina resulted in significant correlation coefficients between N/P and TCH. Tissue P concentrations appeared to be inadequate with respect to K in low yielding fields. This was indicated by highly significant negative correlations between TCH and K/P ratios of the TVD leaf blade, the TVD leaf blade lamina, and the middle of TVD leaf blade. These tissues have the same ranking for Mg/P and Ca/P in their negative correlations with TCH. The middle of the TVD leaf blade gave slightly larger coefficients than the other tissues. No meaningful relationshps were noted for N/K, Mg/N, Mg/K, and Ca/Mg.

The correlation study between the single nutrients and TCH yielded lower coefficients than those found for the nutrient ratios. Significant results for all nutrients were not expected. However, all of the significant results indicated that the TVD leaf blade, the TVD leaf blade lamina, and the middle portion of the TVD leaf blade were more sensitive than other tissues in reflecting the yield-nutrient concentration relationship in the plant.

Precision of Analytical Values Among Tissues

A good diagnostic tissue should exhibit not only sensitivity to external factors but also should have low variation among the replicates. If such variation is too large, the tissue diagnostic method will not be reliable. The coefficients of variation (C. V.) among the replicates of each tissue were generally low for major nutrients but were considerably higher for micronutrients (Table 4). The C. V. values of the TVD leaf blade lamina were as low or lower than those of the other tissues for N, P, and K. The middle portion of the TVD leaf blade, the leaf sheath, and the whole plant were found to be variable for the majority of the nutrients.

TABLE 3. Correlation coefficients (r) between nutrient ratios of each sugarcane tissue and tons of cane/ha (TCH) of the corresponding fields.

Nutrient ratios	TVD leaf blade	TVD leaf lamina	Middle of TVD leaf blade	Middle of elongating leaf lamina	Elongating leaf sheath	Whole plant
N/P	−0.39 *	−0.43 *	−0.36 *	−0.21	0.02	−0.30
N/K	0.11	0.05	0.22	−0.02	−0.13	0.04
Ca/N	−0.40 *	−0.32	−0.41 *	−0.27	−0.18	0.02
Mg/N	−0.13	−0.14	−0.21	−0.17	0.04	0.16
Mg/P	−0.36 *	−0.44 **	−0.48 **	−0.30	0.16	−0.03
Ca/P	−0.62 **	−0.59 **	−0.66 **	−0.38 *	−0.02	−0.28
K/P	−0.45 **	−0.46 **	−0.46 **	−0.20	0.03	−0.28
Mg/K	−0.02	−0.04	−0.01	−0.10	−0.13	0.10
Ca/Mg	−0.23	−0.17	−0.18	−0.13	−0.25	−0.29
N	−0.18	−0.32	−0.01	−0.07	−0.22	−0.33
P	0.32	−0.36 *	0.24	0.07	−0.21	−0.01
K	−0.22	−0.19	−0.39 *	−0.06	0.06	−0.27
Ca	−0.41 *	−0.38 *	−0.36 *	−0.27	−0.30	−0.25
Mg	−0.16	−0.18	−0.21	−0.19	−0.08	−0.04

** * *Significant at 1% level and 5% level, respectively.*

TABLE 4. Coefficients of variation among six sugarcane tissues in the analysis of eight nutrients.

Plant tissues	Plant tissue nutrients							
	N	P	K	Ca	Mg	Mn	Cu	Zn
	C.V. (%)							
TVD leaf blade	4.8	7.4	6.6	4.8	9.2	13.6	10.0	6.2
TVD leaf lamina	2.6	5.4	6.8	7.6	10.0	15.3	10.2	33.6
Middle of TVD leaf blade	8.8	10.0	9.4	13.8	12.2	17.6	22.2	28.9
Middle of elongating leaf lamina	4.6	6.9	6.6	10.7	10.4	11.8	36.9	15.0
Elongating leaf sheath	6.9	11.8	10.1	7.6	10.6	20.0	7.8	18.9
Whole plant	8.9	5.0	13.1	14.2	14.0	15.4	14.3	24.9

The TVD leaf blade resulted in the lowest C. V. values while the TVD leaf blade lamina, the leaf sheath, and the middle of the elongating leaf blade lamina had slightly larger C. V. values for Ca and Mg. The elongating leaf sheaths showed the largest variability for Mn but were the least variable for Cu. Zinc was the least variable in the TVD leaf blade and most variable in the TVD leaf blade lamina.

CONCLUSIONS

The TVD leaf blade, the TVD leaf blade lamina, and the elongating leaf sheaths were better than other tissues for assessing the whole plant nutrient status. However, in terms of sensitivity the TVD leaf blade, the TVD leaf blade lamina, and the middle of the TVD leaf blade best correlated with the plant response. The middle portion of the TVD leaf blade was variable for most nutrients in the replicated samples. Sampling the middle portions of the elongating leaf laminae, the leaf sheath, and the whole plant resulted not only in larger "among replicate sample variability" but also poorer correlations with crop yield. No statistical differences were found in tissue analysis results between the whole TVD leaves and the middle portions of the TVD or elongating leaves. This suggested that the practice of subsampling only the middle portion from the whole leaf is not necessary.

The TVD leaf blade, with or without the midrib, is a good diagnostic tissue. It is a well-defined and easily accessible plant part for sampling. The inclusion of the midrib in the leaf sample decreased N, P, and Mg, increased K, and did not affect Ca, Mn, Cu, and Zn concentrations. Since each tissue has a characteristic nutrient content, interpretation of the results of tissue analysis should always be made on only one tissue.

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COMPARACION DE SEIS TEJIDOS PARA DIAGNOSTICAR EL NIVEL MINERAL DE NUTRIENTES DE LA CAÑA DE AZUCAR

San Thein y G. J. Gascho

RESUMEN

La eleccion de un tejido diagnostico para el analisis mineral de nutrientes en caña de azuacr *(Saccharum* sp., un complejo hibrido de tres especies) varia en todas partes del mundo. El objectivo de este estudio fue comparar seis tejidos diagnosticos que se utilizan en varios paises productores de caña de azucar y seleccionar el mejor en terminos de sensibilidad, precision y aplicabilidad. Los seis tejidos fueron: (1) el limbio de la hoja con la ultima solapa visible (U.S.V.), (2) la lamina de la hoja con la U.S.V., (3) la porcion del medio del limbio de la hoja con la U.S.V., (4) las porciones del medio de las laminas de las hojas en alargamiento, (5) las vainas en alargamiento, y (6) toda la parte de la planta sobre el suelo. Se obtuvieron muestras de cuatro campos comerciales de caña de al Area Agricola de Everglades. Cada campo se dividio en cuatro sitios. En cada sitio se tomaron al azar seis muestras de tejido en duplicado. El diseño experimental fue un bloque al azar completo replicado con los bloques consistiendo los campos y los sitios abrigados dentro de los campos. Las muestras de los tejidos se analizaron para N, P, K, Ca, Mg, Mn, Cu y Zn. Se hizo un estimado del rendimiento de azúcar antes de la cosecha de cada campo. Los datos del limbio de la hoja con la U.S.V., la lamina de la hoja con la U.S.V., y la porcion del medio del limbio de la hoja con la U.S.V. resultaron con relativamente mas altos coeficientes de correlacion entre rendimiento de caña y concentracion de nutrientes. Todos los tejidos estuvieron correlacionados con el nivel de nutrientes en toda la planta. Las concentraciones de nutrienes no fueron estadisticamente diferentes entre el limbio de la hoja con la U.S.V. y la porcion del medio del limbio de la hoja con la U.S.V. La practica de submuestrar la porcion del medio limbio de la hoja con la U.S.V. dio grandes coeficientes de variacion entre replicaciones. La seleccion de la hoja con la U.S.V., con o sin la vena central; aseguro presicion del analisis del tejido proporcionando una baja variabilidad entre replicaciones. La hoja con la U.S.V. es bien definida y facilmente accesible haciendola el tejido de eleccion para estimar el nivel de nutrientes de la caña de azucar.

THE MAXIMUM ECONOMICAL GROWING PERIOD OF SUGARCANE IN MALAYSIA

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ABSTRACT

A field trial was conducted over the period of 1974-1976 to determine the most economical length of growth of four sugarcane varieties, namely GPB 5, GPB 1, GPB 24 and NCo 310. The growing periods tested ranged from 10 to 24 months at 2 months intervals.

NCo 310 which was the main commercial variety planted in the early years of 1969-1973, was used as a check.

The increase of sugar production from 10-14 months was found to be very substantial in all 4 varieties under study. GPB 5 with only 8.70 m.t./ha. sugar yield should not be harvested at 10 months cycle. However, there was a drop of 5% recorded from 12-14 months in case of NCo 310. Increasing cane age has detrimental effect one way or another. GPB 24 and GPB 5 produced 12% more sugar when cane age increased from 14-16 months and were capable of keeping this quality till 18 extra months. Nevertheless, their nominal increase within 4-6 extra months was not economically justifiable.

The 4 varieties tested in this trial under hot and humid climate were found to be suitable for growing more than 16 months. Twelve to fourteen months-cycle will however, be the most economical because of the limited cultivated land and the comparatively cheap cultivation cost. Efforts must be made in breeding early maturing canes of 10 months crop cycle with acceptable cane yield and extremely high sucrose content.

INTRODUCTION

There are many factors responsible for the low sucrose content and yield of sugar cane. Besides the effects of climate which is not possible to control, it had been reported that at least 3 main factors must be taken into account in order to obtain maximum amount of sugar from the standing cane. They are (1) the age of the cane, (2) the effect of variety, and (3) the

type of soil. It was a fact that with the same age and variety, the canes mature earlier in heavy clay soils than in clay and silty loams. Dead stalks are the main cause of lower sugar recovery and poorer population of millable stalks at harvest. Humbert[1] said that there are many factors responsible for dead cane at harvest. Old age, deficiency or excess of moisture, nutritional deficiency and/or toxicity, lodging damage, shading effect, rats, insects and diseases are the factors affecting stalk mortality.

The purpose of this experiment is to find a suitable variety with an optimum, economical length of growth under hot and humid climate in non-irrigated heavy clay soil so as to obtain maximum amount of sugar.

MATERIALS AND METHODS

This experiment was conducted at the Sugarcane Experiment Station, Gula Perak Berhad, Pentai Remis, Perak, Malaysia during 1974-1976. It was a split plot design with four replications. The field was especially laid out to facilitate harvesting at different periods. There were four varieties (main treatment) – GPB 24, GPB 5, GPB 1 and NCo 310 and 8 growing periods (sub-treatment) from 10-24 months, at 2 months interval. Altogether there were 128 sub-plots, each measuring 10 x 7.5 m^2. Every sub-plot had 5 rows of cane planted at 1.5 m spacing. Thirty disease-free two bud-cuttings were planted in each row. All treatments were planted on the same day and harvested according to the growing periods. The dates of field operations are shown in Table 1.

Each sub-plot received 140-180-140 kg/ha of N, P_2O_5 and K_2O in two equal applications prior to planting and 2 months later.

In each sub-plot, 15 representative stools were selected and numbered for vegetative measurements which started at the 8th weed and thereafter at 4 week intervals until the cane was 9 months old. The measurements included the height of plant or stem, number of tillers per stool, and the number of internodes and green leaves.

At harvest, all the canes in the middle 3 rows of each sub-plot were cut at ground level and topped at about 30 cm from the first collar. The weight and number of millable stalks were recorded as well as the number of water stalks (suckers), dead stalks, tasselling stalks and degree of rat damage. In addition, 25 stalks from the guard rows of each sub-plot were selected for assessing the number of green leaves, bored joints caused by stem borers, pith formation, number of internodes per stalk, stalk length and diameter. Lodging and infestation by aphids were estimated through visual observation at time of harvest.

RESULT AND DISCUSSION

Stand of the canes

The total rainfall for the month of September, 1974 was 296.16 mm

which was adequate for germination. As shown in Table 2, variety GPB 24 germinated faster than the other three varieties. In contrast, variety GPB 5 was found to germinate with only 21.01% recorded at the end of 14 days. The differences in germination rate between varieties can be arranged as follows: GPB 24 > NCo 310 > GPB 1 > GPB 5; and performance, GPB 24 > GPB 5 > NCo 310 > GPB 1.

Table 4 a, b, and c showed the data on vegetation measurement. It can be seen that NCo 310 was more profuse in tiller population and GPB 1 was dominant in growth. The mortality rate of young tillers from 8-36 weeks was more severe in GPB 5 (about 18%). The average number of internode formation was about 2-4 per month (Table 4c). The number of green leaves reduced with maturity. There was a positive correlation between the tiller population and number of green leaves per stalk. NCo 310 with denser stooling, produced more green leaves. In contrast, GPB 1 had least number of green leaves and poorest tiller population.

Table 5 (a 1) and 5 (a 2) present the characteristics of individual stalks of each variety at different ages of harvest. In general, number of internodes and length of stalk increased with cane age. The green leaves decreased with aging of the cane. There seemed to be little correlation between weight and diameter of stalk with the cane age. However, the three new varieties were found to be thicker and heavier than NCo 310. Among them all, GPB 1 was the thickest and heaviest. As cane age increased, the top brix of GPB 1 and GPB 5 had a tendency to decline. This accounted for poor rendement when compared with varieties GPB 24 and NCo 310. GPB 24 had a very steady and even brix throughout the growing period.

From Table 5 (b), it can be seen that % of water stalks (suckers) of all the four varieties slightly increased from the 10th month to the 12th or 14th month then gradually dropped as the cane became older. This phenomenon clearly inidcated that the suckers turned into millable stalks as the growing period lengthened. Wooly aphids infestation was more prevalent with NCo 310. This might be due to the morphology of the stool which was comparatively denser with considerably larger leaf-surfaces. Pith formation and flowering were the two main defective physiological characteristic of GPB 5.

Early and heavy lodging was the main cause of high stem borer attack and stalk mortality. In 24 months the % of bored joints of GPB 1 was as high as 15.41 and the % of dead stalk was 66.24.

2. *Correlation of % dead stalks, % bored joints caused by stem borers and millable stalks of different varieties in different growing periods*

As seen in Fig. 1, the mortality rate gradually increased with age in all varieties. However, the increase in % of dead stalks due to aging was less conspicuous with GPB 24. At 24 months of cane age, the percentages of dead stalks of NCo 310, GPB 1, GPB 5 and GPB 24 were 78.62, 66.24, 57.60 and

39.01 respectively.

The number of millable stalks of these varieties were in the following order: NCo 310, GPB 24, GPB 1. In comparing the number of millable stalks per hectare, it was found that NCo 310 was more prominent at 10 months of cane age and decreased in number in the following months, except at 18 months. This might be due to the second tillering period of this variety. All the varieties attained the highest peak in millable stalks from 16-18 months of age, decreasing tremendously thereafter as the mortality increased sharply. The mortality rate can be arranged in the order of: NCo 310, GPB 1, GPB 5, and GPB 24.

As seen in Fig. 2, there seemed to be little or no relationship between the mortality of cane and % of bored joints. However, it was related to the variety. GPB 1 and NCo 310 were more susceptible to the borer attack. In GPB 1, the incidence of bored joints was as high as 15.41% at 24 months of growth. GPB 24 and GPB 5 were comparatively resistant in this respect.

3. *The rate of mortality and bored joints as affected by lodging.*

Lodging was the main cause of high percentages of dead stalk at harvest GPB 1 or NCo 310 are soft canes and therefore mortality and bored joints of stalk were more severe. The condition was especially severe in GPB 1 which had the fastest stem elongation. The low % of bored joints observed in GPB 24, though it also lodged seriously after 14 months old, was attributed to harder and hairy leaf sheaths which protected the stem from exposure to the attack.

4. *Interaction of growing period and cane yield.*

As seen in Fig. 3, all four varieties reached the peak of cane production at 16-18 months of age and produced 21-23% more cane yield than at 12 months. GPB 24 was more consistent in cane yield as age increased. There was a very conspicuous drop in GPB 1 and NCo 310 after peak cane age to 24 months. The best cane yield was obtained from GPB 1 at 16 months which produced 161.43 m.t./ha.

5. *Interaction of growing period and sucrose content.*

From Fig. 4, it can be seen that the sucrose content measured as available standard sucrose % cane varied widely with variety and length of growth. NCo 310 was an early sugar producer at 12 months and was the highest of all varieties (13.75%). GPB 1 was found to be a very late and low sugar accumulator at 20 months (12.14%). From these facts, it clearly indicates that the peak month in cane yield does not infer the optimum length of growth. However, GPB 24 and GPB 5 attained quite similar curves in cane yield and sucrose content in relation to length of growth.

6. *Sugar yield*

More sugar in the bag is the ultimate goal of sugarcane cultivation. In

TABLE 1. Growing period and harvesting date

Growing period (months)	Harvesting date	Weather condition
10	2-7-1975	good
12	2-9-1975	good
14	2-11-1975	good
16	2-1-1976	fair
18	2-3-1976	good
20	2-5-1976	good
22	2-7-1976	good
24	2-9-1976	good

TABLE 2. Germination rate; Date of 1st investigation: 16-9-1974; Date of 2nd investigation: 30-9-1974

Variety / Growing periods (months)	GPB 24		GPB 5		GPB 1		NCo 310	
	16-9-'74	30-9-'74	16-9-'74	30-9-'74	16-9-'74	30-9-'74	16-9'74	30-9-'74
10	95.97	99.04	16.08	88.11	47.06	71.02	75.04	92.80
12	92.12	98.16	18.59	93.30	47.40	72.52	76.71	91.96
14	88.27	96.48	13.23	92.63	43.71	67.50	69.68	92.63
16	89.11	97.65	27.47	91.63	43.71	63.99	61.97	88.78
18	90.78	98.83	23.45	91.62	70.18	86.26	76.71	91.62
20	85.09	99.92	18.42	96.65	73.70	91.96	73.03	95.81
22	94.63	99.33	18.09	94.47	75.54	89.11	56.28	92.96
24	90.95	99.66	33.50	95.18	78.55	92.46	57.78	94.47
Average	90.87	98.63	21.10	92.95	59.98	79.35	68.40	92.63

Germination rate : GPB 24 > NCo 310 > GPB 1 > GPB 5
Performance : GPB 24 > GPB 5 > NCo 310 > GPB 1

TABLE 3. Meteorological data during the trial

Items	Period: Sept., 1974 – August, 1975	Period: Sept., 1975 – August, 1976
Daily average relative humidity (%)	86.30	86.90
Daily mean temperature °C	27.30	29.30
Daily mean maximum temperature °C	34.00	36.70
Daily mean minimum temperature °C	21.50	22.90
Diurnal temperature range °C	12.60	13.80
Daily average sunshine hours	6.90	7.80
Total annual rainfall (mm)	2,658.60	2,270.04

principle, it is preferable to have a variety of moderately high cane yield with extremely high sucrose content than an extraordinary cane yielder with a low sucrose content, because the extra cost of cutting and transporting will certainly reduce the margin of profit. Such was the case in comparing the sugar yield of GPB 1 with GPB 24, and GPB 5. This relation is further illustrated in Fig. 5. There was an increase of 10 and 18% in cane yield of GPB 1 over GPB 24 and GPB 5 respectively, but due to its low sucrose content, the increase in sugar yield was only 5 to 2% respectively. In general, the sugar yield decreased with age in accordance with the decrease in cane yield and rendement of each variety. There was one exception in the case of 16 month NCo 310. This had been explained earlier that it might be due to the maturing of the secondary tillers.

TABLE 4(a) Average number of tillers per stool

Variety	Cane age in weeks							
	8	12	16	20	24	28	32	36
GPB 24	4.90	4.56	4.30	3.90	3.38	2.90	3.42	3.31
GPB 5	4.74	4.57	4.88	4.16	3.54	3.10	3.02	2.67
GPB 1	3.06	3.07	2.91	2.93	2.52	2.49	2.55	2.67
NCo 310	5.35	6.62	5.68	5.58	5.01	4.74	4.93	4.86

TABLE 4(b) Average height of plant and stem (cm)

Variety	Cane age in weeks							
	8	12	16*	20**	24	28	32	36
GPB 24	159.90	229.20	225.60	159.40	169.80	234.30	289.20	289.20
GPB 5	136.50	199.90	226.80	119.10	145.50	191.40	240.60	247.80
GPB 1	171.00	225.30	252.30	171.30	208.10	248.10	312.00	324.00
NCo 310	129.90	183.00	204.90	116.10	144.90	184.20	237.30	243.30

* *Height of plant* ** *Height of stem*

TABLE 4(c) Average number of internodes and green leaves per stalk

Variety	Cane age in weeks							
	Av. no. of internodes per stalk*				Av. no. of green leaves per stalk			
	24	28	32	36	24	28	32	36
GPB 24	6	10	14	16	11	11	11	11
GPB 5	5	9	12	14	10	10	10	10
GPB 1	8	14	20	21	11	10	10	9
NCo 310	4	8	13	15	12	12	11	11

* *No. of internodes up to bottom of green leaf sheath*

TABLE 5 (a 1) Crop Measurement

Variety	Growing period (months)	No. of inter-nodes	No. of green leaves	Length of stalk (m)	Diameter of stalk (cm)	Weight of stalk (kg)	Brix		T/B ratio
							Top	Bottom	
	10	25	11	3.04	2.45	1.55	16.65	17.74	0.9386
	12	31	11	3.52	2.38	1.67	17.94	17.94	1.0000
	14	35	11	3.74	2.47	1.78	19.66	18.88	1.0413
GPB 24	16	42	11	4.27	2.45	1.86	18.12	17.97	1.0083
	18	45	9	4.72	2.41	2.06	19.32	18.18	1.0627
	20	48	9	4.67	2.30	1.95	19.02	19.11	0.9953
	22	49	10	4.85	2.46	2.13	20.05	18.37	1.0915
	24	47	10	5.45	2.56	2.09	20.68	17.36	1.1912
	10	23	11	2.67	2.57	1.63	15.64	19.05	0.8210
	12	30	11	3.32	2.68	1.93	16.81	19.30	0.8710
	14	35	11	3.50	2.65	1.93	18.28	19.12	0.9561
GPB 5	16	37	10	3.45	2.47	1.92	15.48	18,02	0.8590
	18	38	10	3.61	2.58	2.12	16.20	17.64	0.9184
	20	39	10	3.52	2.50	1.89	16.06	18.35	0.8752
	22	38	9	3.53	2.70	2.13	15.33	17.09	0.8970
	24	44	9	4.82	2.78	2.37	15.12	16.05	0.9421

TABLE 5 (a 2) Crop measurement

Variety	Growing period (months)	No. of inter-nodes	No. of green leaves	Length of stalk (m)	Diameter of stalk (cm)	Weight of stalk (kg)	Brix		T/B ratio
							Top	Bottom	
GPB 1	10	28	10	3.32	3.04	2.13	11.56	16.16	0.7153
	12	34	9	4.21	2.82	2.47	11.90	15.70	0.7637
	14	40	8	4.58	2.91	2.62	12.63	16.72	0.7554
	16	42	8	4.82	2.81	2.74	12.19	16.67	0.7313
	18	50	8	5.90	2.74	2.85	13.78	15.60	0.8833
	20	45	7	4.69	2.78	2.45	12.19	19.12	0.6727
	22	44	7	4.69	2.79	2.56	12.55	17.54	0.7155
	24	51	7	6.10	2.89	2.34	11.30	16.45	0.6869
NCo 310	10	24	11	2.62	2.17	1.00	15.45	17.73	0.8714
	12	30	12	3.11	2.18	1.16	17.45	18.08	0.9652
	14	36	12	3.42	2.20	1.21	19.52	18.16	1.0749
	16	42	11	3.89	2.19	1.55	18.21	16.65	1.0937
	18	44	10	3.83	2.23	1.42	19.05	17.88	1.0654
	20	43	11	3.27	2.34	1.31	19.66	16.88	1.1647
	22	44	11	3.21	2.50	1.39	20.22	16.87	1.1986
	24	46	11	4.37	2.44	1.21	20.05	16.65	1.2042

TABLE 5 (b 1) Crop measurement — Losses at harvest

Variety	Growing period months	% Water stalk	% Aphis infestation	% By joints pith formation	% Flowering	Lodging condition
GPB 24	10	6.15	1.25	——	——	//
	12	9.56	——	——	——	//
	14	5.30	1.25	——	——	=
	16	2.66	——	——	——	=
	18	1.84	——	——	——	=
	20	1.96	——	——	——	=
	22	2.97	——	——	——	=
	24	1.93	——	——	——	=
GPB 5	10	2.29	3.75	0.30	——	||
	12	7.52	——	0.90	——	||
	14	8.50	1.75	14.34	33.30	||
	16	4.53	——	10.54	33.82	||
	18	4.56	——	9.49	27.16	||
	20	3.64	——	8.81	13.68	||
	22	3.54	——	7.57	13.94	//
	24	3.73	——	1.96	8.84	//

Lodging condition: || *Standing cane;* // *Less than 30%;* // *30% – 50%;* = *50% (completely lodged)*

TABLE 5 (b 2) Crop measurement – Losses at harvest

Variety	Growing period months	% Water stalk	% Aphis infestation	% By joints pith formation	% Flowering	Lodging condition
GPB 1	10	5.29	—	3.70	—	=
	12	3.48	—	—	—	=
	14	4.51	—	—	—	=
	16	3.64	—	—	—	=
	18	2.57	—	—	—	=
	20	2.81	—	—	—	=
	22	2.82	—	—	—	=
	24	1.38	—	—	—	=
NCo 310	10	2.04	6.25	—	—	//
	12	5.09	—	—	0.06	=
	14	7.10	3.75	—	—	=
	16	5.29	—	—	—	=
	18	3.96	—	—	—	=
	20	3.08	—	—	—	=
	22	4.77	—	—	—	=
	24	2.92	—	—	—	=

Lodging condition: || *Standing cane;* // *Less than 30%;* // *30% – 50%;* = *50% (completely lodged)*

TABLE 6. Sugar yield (m.t./ha.)

Variety	Growing period (months) 10	12	14	16	18	20	22	24	Average
GPB 24	10.38	14.82	15.64	17.52	16.92	15.50	14.94	13.21	14.87**
GPB 5	8.70	13.27	14.32	16.17	17.95	11.03	9.88	9.25	12.57*
GPB 1	8.72	13.44	15.63	18.36	16.42	13.00	8.89	5.32	12.45*
NCo 310	8.82	14.16	13.47	14.91	16.02	10.23	5.98	3.81	10.93
Average	9.16	13.92**	14.72**	16.74**	16.83**	12.44*	9.92	7.90	L.S.D. 5% = 1.31
L.S.D.		5% = 3.09		1% = 4.10					1% = 1.88

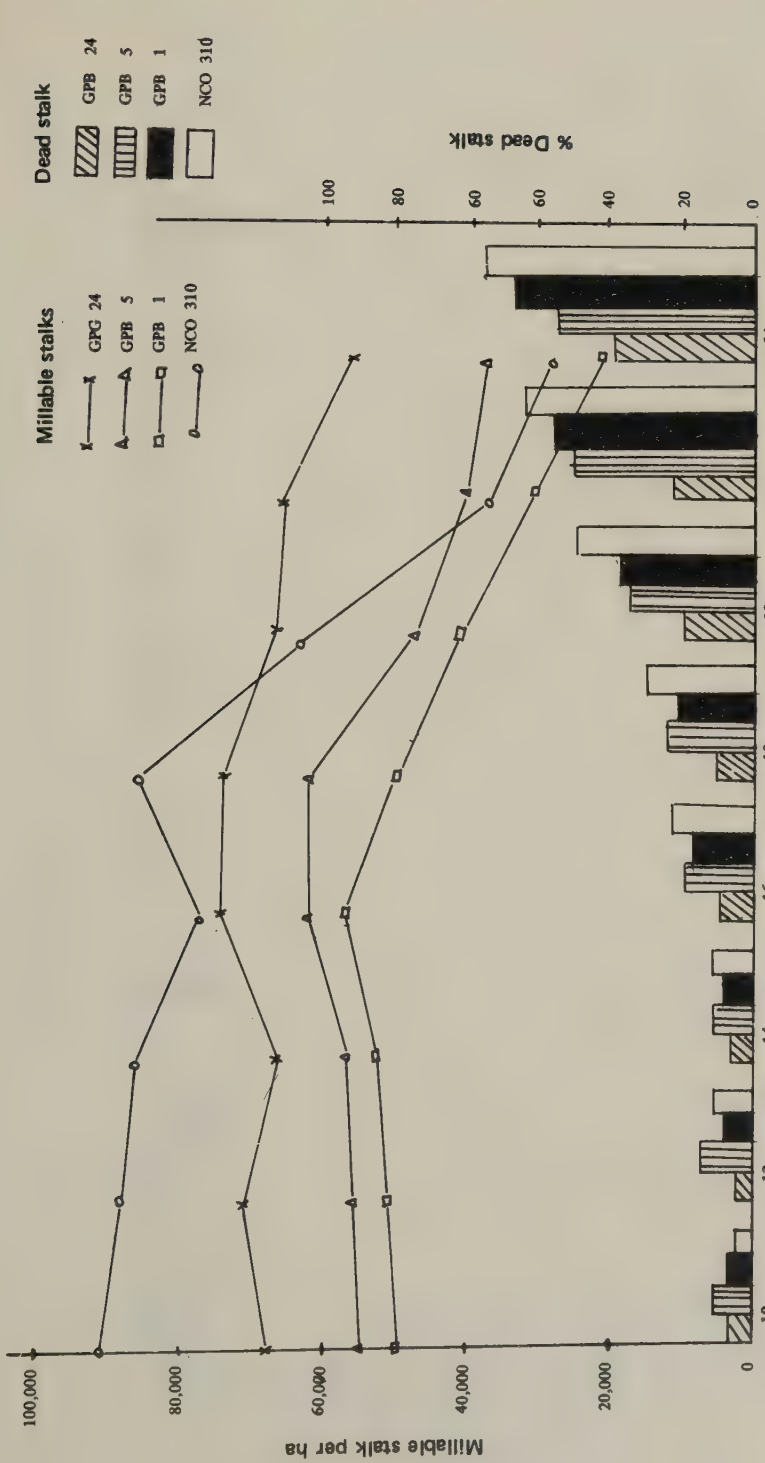

FIGURE 1. Number of millable stalk per ha and % dead stalk.

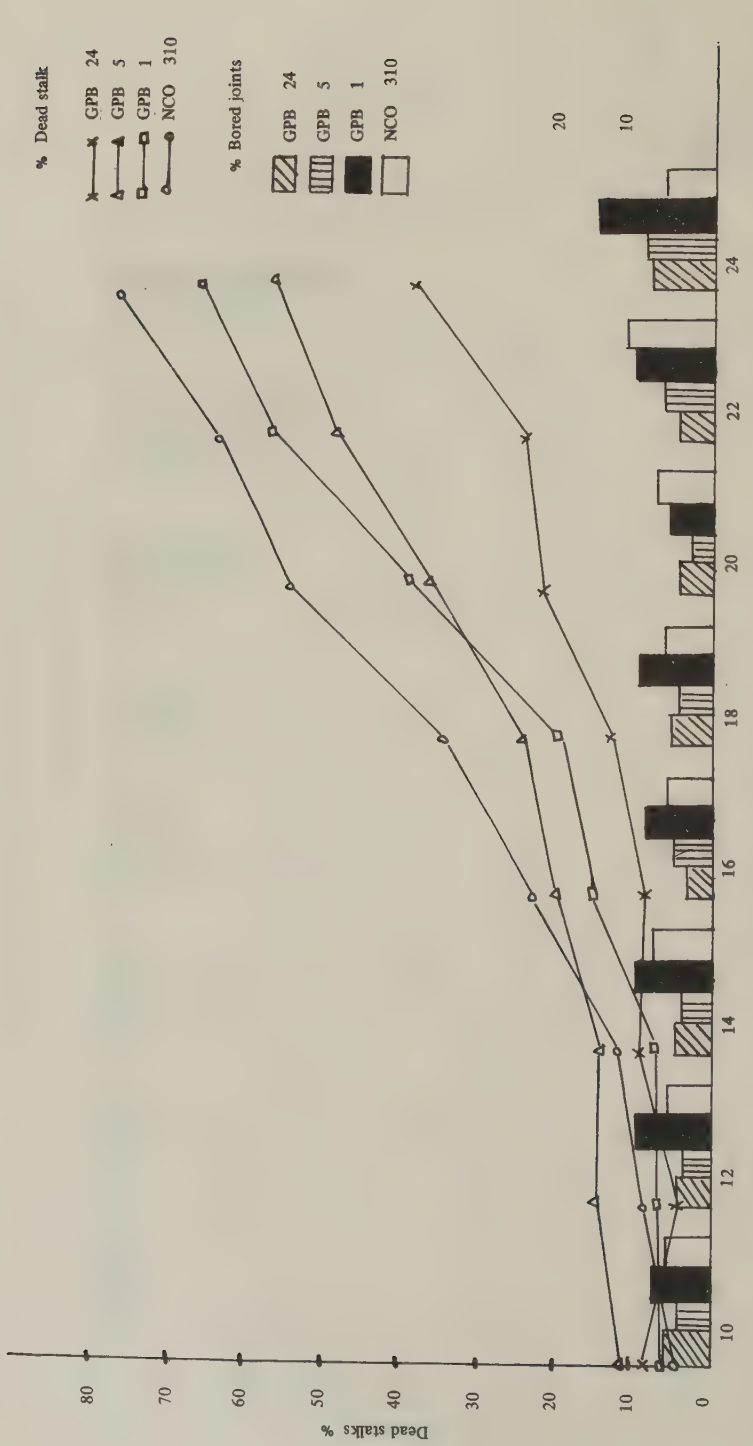

FIGURE 2. Dead stalks % and bored joints

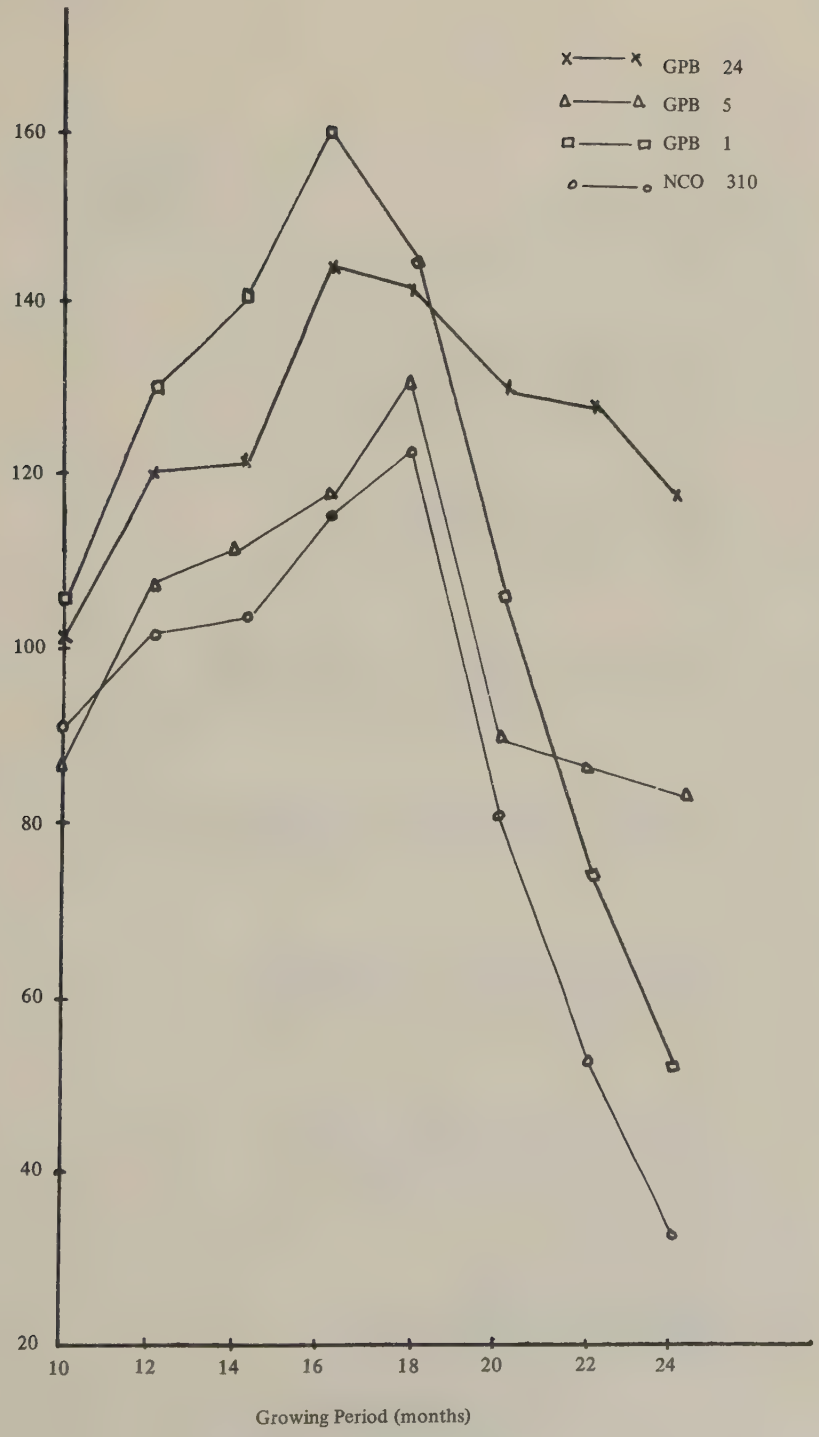

FIGURE 3. Cane yield (m.t./ha)

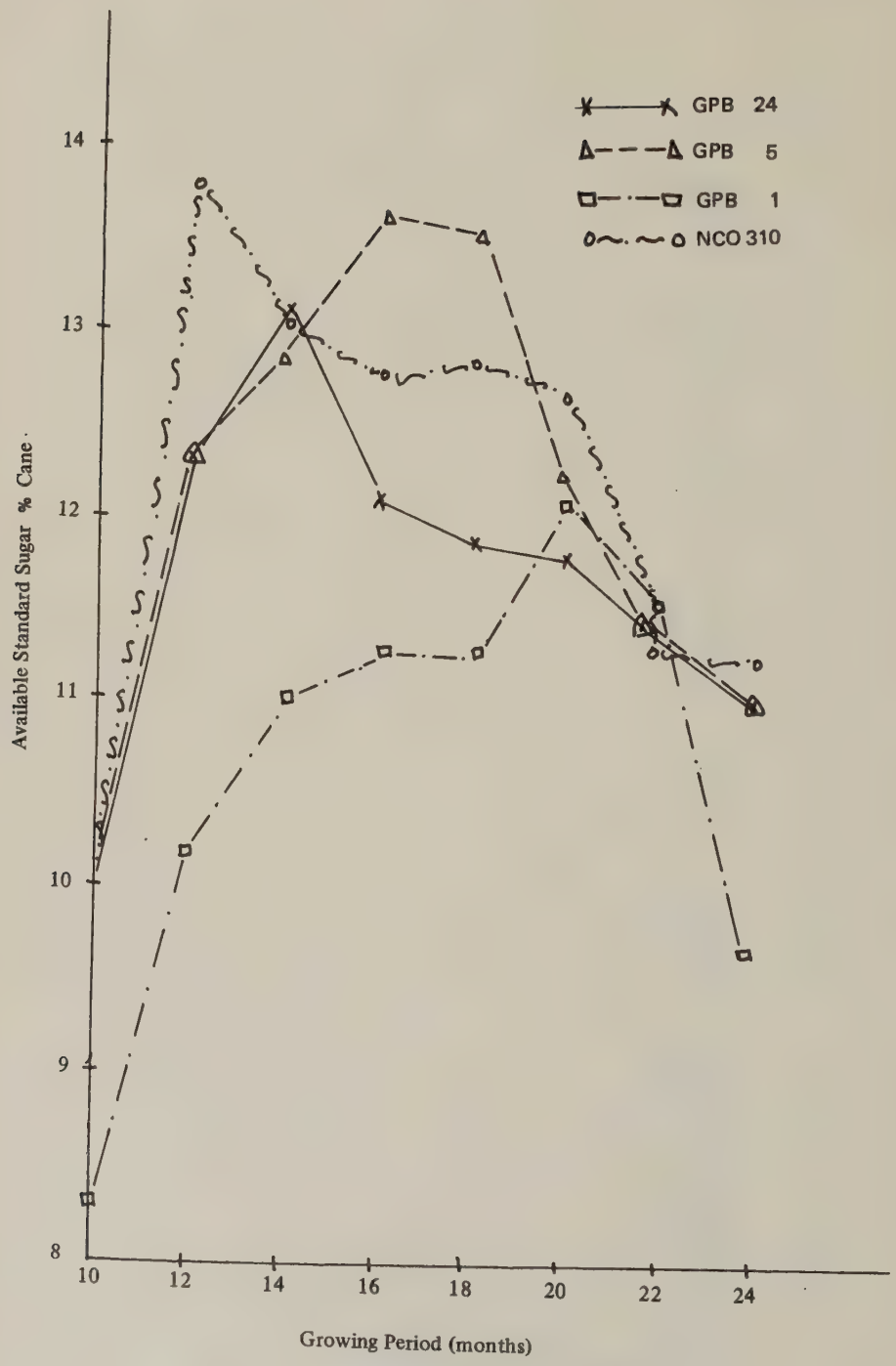

FIGURE 4. Available Standard Sugar % Cane

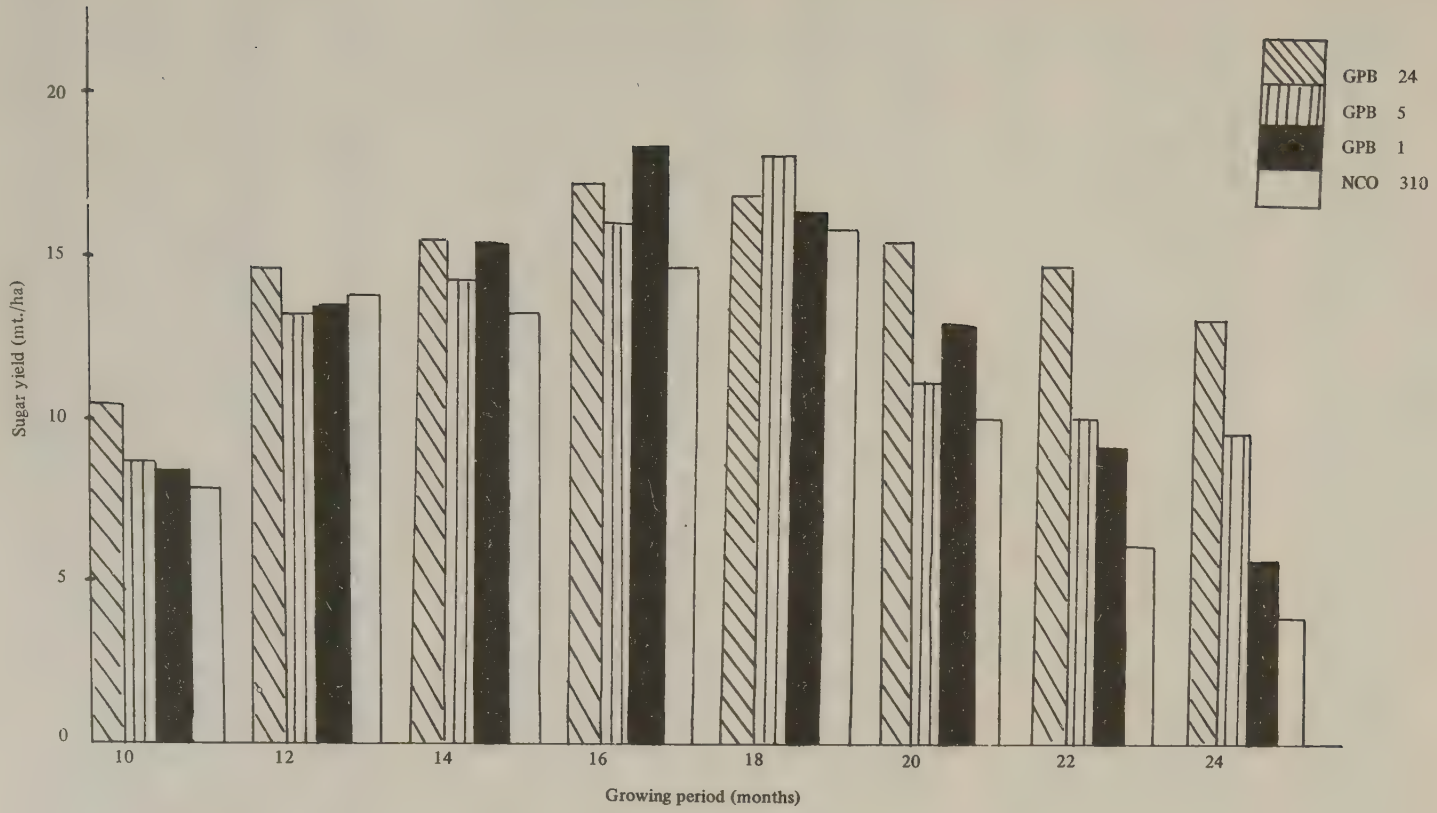

FIGURE 5. Sugar yield (m.t./ha)

CONCLUSION

It was found that the high mortality rate and heavy lodging observed with increasing age, accounted for the lower sugar recovery in all four varieties -- GPB 1 with 80% dead stalks and NCo 310 with 70% dead stalks at 24 months of growth.

From the evidence obtained in this trial, it can be deduced that the optimum growing periods for these four varieties should not be less than 12 months and not more than 16 months. In fixing an optimum growing period for a certain variety under certain environmental conditions, besides considering the cane and sugar yield, factors such as maximum use of land, crop costs, harvesting and transporting costs must be taken into consideration.

Basing on the unit area sugar production and other related factors, it can be recommended that:

1. NCo 310 which is an early maturing variety should be harvested on a 12 months crop cycle. However, it was replaced by other varieties because of its great susceptibility to smut infestation and ratoon-stunting disease.

2. GPB 24 and GPB 5 which are intermediate in cane and sugar yield with upright characteristics, were the better varieties for extension in this area and should be harvested at 12-24 months.

3. GPB 1 which is heavy lodged with thick canes high cane yield is a very low and late sugar accumulator. This variety has extremely high cane yields (as high as 160 m.t./ha) at 16 months, but extremely low and late sugar of 12% available standard sugar % cane at 20 months. The first 3 other varieties had reached 13-14% at 14 months. It is not suitable for large scale planting in this area because not only will the cost of harvesting and transporting increase, but the delivery of cane to the mill after burning will be greatly delayed due to difficulties in cutting.

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EL MAXIMO PERIODO DE CRECIMIENTO ECONOMICO DE LA CAÑA DE AZUCAR EN MALASIA

Y. C. Pan, K. L. Eow y T. H. Su

RESUMEN

Se llevó a cabo un ensayo de campo durante el periódo 1974-1978 para determinar la duración de tiempo de crecimiento mas economico para cuatro variedades de caña de azucar, señaladamente GPB 24, GPB 5, GPB 1 y NCo 310. Los periodos ensayados fueron 10-24 meses a intervalor de 2 meses.

NCo 310, que fue la principal variedad comercial sembrada durante los años 1969-1973, sirvió de testigo en este ensayo.

El aumento en producción de azucar de 10-14 meses fue muy substancial en las 4 variedades bajo prueba. La variedad GPB 5 en especial, no se debe cosechar en un ciclo de 10 meses con rendimiento de azucar de solamente 8.70 t.m./ha. No obstante, hubo una merma de 5% de 12-14 meses en el caso de NCo 310. El aumentar la edad de la caña tuvo un efecto detrimental en una forma u otra. GPB 24 y GPB 5 produjeron 12% más azúcar cuando la edad de la caña aumento de 14-15 meses, pudiendo mantener esta calidad hasta los 18 meses. Sin embargo, este modico aumento logrado en 4-6 meses más no fúe economicamente justificable.

Las 4 variedades probadas en este ensayo bajo un clima caliente y húmedo se encontraron adaptables para crecer más de 16 meses. Sin embargo ciclos de 12-14 meses serían los más económicos, debido a la poca disponibilidad de terreno cultivable y los comparativamente bajos costos de cultivo, se deben hacer esfuerzos para lograr a traves de mejoramiento varietal una variedad de madurez temprana de un ciclo de 10 meses con rendimiento aceptable de caña y extremadamente alto contenido de sacarosa.

POTASSIUM AVAILABILITY IN SOILS OF THE SOUTH AFRICAN SUGAR BELT

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ABSTRACT

Soil potassium measured by various extraction procedures was compared with potassium availability assessed during continuous cropping of rye grass and sorghum in pots on a wide range of soils from the South African sugar belt. For both the ammonium acetate and nitric acid extractable potassium methods, there was a highly significant positive correlation ($r = 0.80$) between clay content and threshold value. It was concluded that the single threshold value currently used to predict potassium fertilizer requirement for sugarcane in South Africa is inadequate. There was little advantage in using, for advisory purposes, the nitric acid method in preference to the currently used ammonium acetate procedure on light medium textured soils, as the latter method quite closely predicts potassium availability in these categories. However, the NEAK value (nitric acid K – ammonium acetate K) could be used to advantage on heavy textured soils, as it provides a better measure of the ability of these soils to supply potassium on a long term basis.

INTRODUCTION

In a paper on potassium in sugarcane production Wood[9] drew attention to some of the problems in predicting cane potassium requirement. Meyer *et al*[8] in a nutrient survey of the South African sugar industry reported that there was often poor agreement between leaf K values and corresponding soil exchangeable K values. More than 18% of leaf samples examined showed marginal to low K values while the corresponding soil samples had adequate to high levels of exchangeable K. A re-examination of the data by Burrows[3] using current threshold values of 1.05% per leaf K, and 112 ppm for soil K showed that 31% of leaf samples from cane grown on soils derived from Lower Ecca Shales, and 45% from doleritic soils of the Nkwalini Valley and alluvial soils of the Monzi area still showed this anomalous effect. Subsequently similar anomalies were observed in 5 month-old cane sampled in October and November on several estates in Swaziland.

The ability of a soil to release K from potassium containing minerals

is known as potassium-supplying power'. Alexiades[1] suggested that it is the result of two factors, namely, one related to the exchangeable and soluble K in the soil, and the other to the slowly available K and the rate that this form of K becomes available to plants following uptake of the readily available forms. Haysom[6] expressed doubt that the level of soil exchangeable K as a single value forms a sound basis for predicting fertilizer requirements. He developed a method which measured part of the non-exchangeable soil K which together with the exchangeable form gave a better correlation with crop response.

It is now generally accepted that plants obtain their K requirements from the soil solution directly, the K ions moving to the plant roots either by mass flow or diffusion (Grimme *et al*[5]). Calcium chloride extractable or labile K was considered by Koch[7] as a better index of K availability since soils with the same exchangeable value can differ widely in their ability to supply K to the plant and in their ability to buffer the soil solution against variation in K status when K is progressively removed by cropping.

In view of the discrepancies between soil K and leaf K values previously mentioned, it was felt that a measure of the ability of our soils to supply potassium could have considerable importance particularly as it relates to current K fertilizer recommendations. This paper reports on how effective exchangeable K and other extraction procedures have been in predicting the long term K supplying power of a range of sugar belt soils during continuous cropping in a glasshouse experiment.

MATERIALS AND METHODS

Soils

Twelve soils with widely differing characteristics were selected. Some, including two from Swaziland, were from areas where the low leaf K/high soil K anomalies have been reported, while others were from areas in which cane had been cultivated continuously for many years. A summary of some of the relevant features of the soils is given in Table 1. All but the Cartref series subsoils (30-45 cm) were top-soil samples (0-15 cm), which were air-dried, then crushed and passed through a 2 mm sieve, after which they were mixed thoroughly before being placed in pots. Kaolin is the predominant clay mineral in the majority of these soils.

Glasshouse technique

The relevant mass of each soil was placed in 24 pots such that it occupied a specific volume (1 liter). There were four treatments and six replicates for each soil:

i) no potassium added (KO)

ii) potassium added at a rate equivalent to 75 kg/ha before sowing (K1)

TABLE 1. Some properties of the soils used

Soil series	Parent material	pH	Clay %	CEC	Exch K me %	Clay minerals*
Fernwood	Recent sand	5.6	4	3.2	34	K
Cartref (T)†	Table mountain sandstone	5.8	5	2.9	147	K + mi
Cartref (S)†	Table mountain sandstone	5.5	8	3.1	52	K + mi
Clansthal	Recent sand	4.9	15	3.1	83	K
Waldene	Dwyka tillite	6.0	19	8.9	145	K + e
Shorrocks	Alluvium	6.9	20	9.6	92	K + m + mi
Tambankulu	Dolerite/basalt	6.4	31	24.1	92	K + I + m
Glendale	Tugela schist	5.0	33	9.1	244	K
Milkwood	Lower Ecca	6.0	37	22.4	402	K + V + mi
Rydalvale	Dolerite	5.8	39	26.8	85	K + m
Rondspring	Dolerite/basalt	5.1	44	22.9	168	K + I + m
Phoenix	Alluvium	6.2	44	27.2	268	M + K

* *Capitals indicate dominant and small letters accessory minerals: I, illite; K, kaolin; M, montmorillonite; V, vermiculite; MI, mica.*

†*T, topsoil; S, subsoil*

iii) potassium added at a rate equivalent to 150 kg K/ha before sowing and at the same rate after each harvest (K2)

iv) unplanted pots of soil (no K fertilizer added), sampled one week after the trial commenced, and at the same time as the K0, K1, K2 treatments were harvested.

At planting a standard nutrient solution containing all the essential elements apart from potassium was applied to all seeded pots, and again at intervals during the experiment. In addition, nitrogen was applied regularly to all crops every 7-14 days, between cuts. Throughout the experiment, all pots were maintained at 60% of the maximum water holding capacity by daily watering. Initially ryegrass was used as the test crop but as the trial progressed it was replaced by forage sorghum. This was found to grow faster and regenerate more rapidly after cutting, thereby accelerating the nutrient exhaustion process.

Harvesting

Cutting of tops commenced some five weeks after sowing and successive cuts were taken at regular intervals. When necessary the pots were re-seeded and crops harvested until further growth was negligible in the K0 and K1 treatments. All cuts were oven-dried overnight at 70°C, weighed and ground for analysis. At an intermediate stage (usually the third or fourth cut of the first planting) tops and roots were removed from two replicates of each treatment and analyzed together with the soil. The remaining four replicates were similarly treated when growth finally ceased.

Analytical methods

Potassium was measured in all extracts by means of a Varian 1200 Atomic Absorption Spectrophotometer using appropriate standards.

1. *Total K (plants and roots)*

Digest 0.5 g dried material with 4.5 ml selenized sulphuric acid for 1-1/4 hours. Dilute the digestate with water up to 50 ml.

Total K (soils)

Digest 0.4 g soil in 1 ml aqua regia plus 6 ml hydrofluoric acid in a Uniseal decomposition vessel at 11°C for 20 minutes. Decant into a polythene beaker, add 5.8 g boric acid, dilute to 100 ml, and take a 10 ml aliquot (Bernas[2]).

2. *Soil K fractions*

a) Shake 10 g soil with 100 ml 1N ammonium acetate for 20 minutes. Centrifuge and dilute an aliquot of the supernatant.

b) *Calcium chloride K*

Shake 10 g soil with 100 ml 0.010m calcium chloride for 20 minutes. Centrifuge and dilute as above. This procedure is based on the method of Woodruff and McIntosh[10], and measures the pool of labile K in the soil.

c) *Nitric acid soluble K*

Reflux 2.5 g soil with 100 ml 1N nitric acid for 30 minutes. Filter and dilute with water to 200 ml. This procedure is based on the method used by Haysom[6], and has two distinct applications. First the nitric acid value may be used as a soil test criterion. Secondly, when used in conjunction with the exchangeable K value, the difference between the two values provides a measure of the fixed or non-exchangeable available K (NEAK).

Threshold values

For each soil, the mean K0 and K1 treatment yields expressed as percentage of the K2 treatment yields, were plotted against accumulated net crop K uptake per pot excluding roots as shown for the Shorrocks series soil in Figure 1. From this graph, net K uptake at the threshold value was considered to be the point at which the yields from the K0 and K1 treatments, when compared with the K2 treatment yield began to decline consistently. This information was used to assess the soil test values at threshold for the three extraction procedures described above. When a pot was destructively harvested during the process of exhaustion the net K uptake by the crop including roots (root contribution to net K uptake was generally insignificant) was plotted against the respective soil test values obtained at the time. The graph in Figure 2 shows how the ammonium acetate value at threshold was derived for the Shorrocks series soil.

RESULTS AND DISCUSSION

Table 2 shows the amount of potassium taken up by the crop, from the start of cropping until the threshold value was attained in the 12 soils, together with the changes that occurred in the ammonium acetate, calcium chloride and nitric acid soil test K values during the same period. The values for the Phoenix, Milkwood and Rondspring soils are only approximate as after 21 months of continuous cropping the K0 treatment was still releasing sufficient quantities of potassium to meet much of the crop requirements.

From the ammonium acetate and nitric acid soil test data, it was apparent that there was a wide range of threshold values for the various soils. For both tests, there was a highly significant positive correlation ($r = 0.80$) between clay content and threshold value as shown in Figures 3 and 4.

The ability of the three soil test methods to predict K availability on

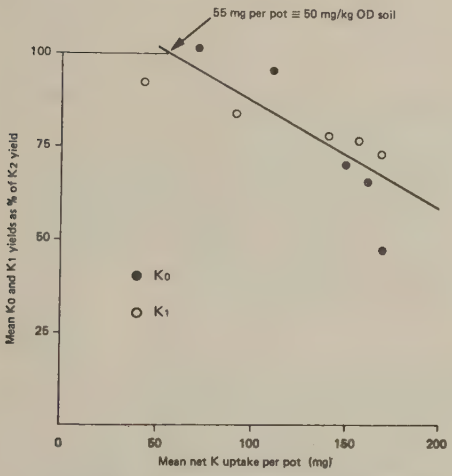

FIGURE 1. Determination of net K uptake at threshold (mg/kg oven dry soil) for the Shorrocks series soil

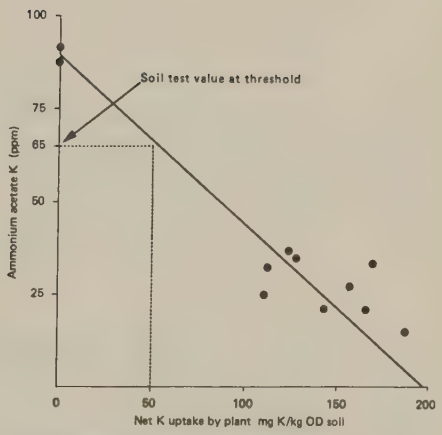

FIGURE 2. Determination of ammonium acetate soil test value at threshold for the Shorrocks series soil

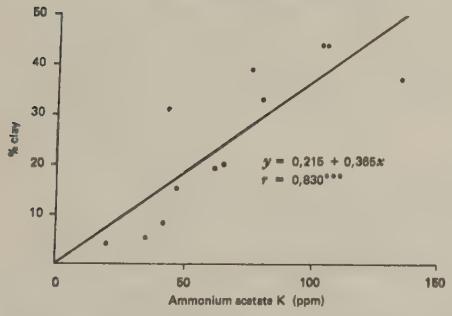

FIGURE 3. The relationship between clay content and soil test value at threshold (ammonium acetate extract)

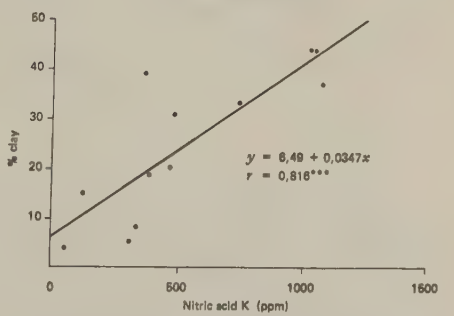

FIGURE 4. The relationship between clay content and soil test value at threshold (nitric acid extract)

the basis of soil texture was examined more closely. The soils were divided into three categories based on clay percentages, namely, less than 16%, 16-35% and more than 35%. From the data in Table 2, the availability of K per unit change in soil test value above the mean threshold value for soils within the three clay categories defined above, was determined as shown in Table 3.

Ammonium acetate method

For loamy sands and sands (less than 16% clay) this procedure fairly accurately predicted K availability and was reasonably satisfactory for sandy loams and sandy clay loams (16-35% clay). For sandy clays and clays (more than 35% clay) however, the test was of limited value since on the average,

TABLE 2. Potassium balance sheet at the time threshold value was attained

Soil series	Clay %	K uptake at threshold mg/kg *OD soil	Ammonium acetate (Exch-K) ppm			Calcium chloride K ppm			Nitric acid K ppm			†NEAK ppm
			Initial	At **TV	K	Initial	At TV	K	Initial	At TV	K	
Fernwood	4	23	34	20	14	16	10	6	88	60	28	54
Cartref (T)	5	134	147	35	112	116	28	88	430	310	120	283
Cartref (S)	8	13	52	42	10	37	28	9	350	338	12	298
Clansthal	15	35	83	47	36	59	34	25	148	120	28	65
Waldene	19	130	145	62	83	108	35	73	468	380	88	323
Shorrocks	20	50	92	65	27	41	30	11	520	465	55	428
Tambankulu	31	92	92	43	49	33	7	26	513	480	93	481
Glendale	33	200	244	80	164	160	25	135	927	740	187	683
Milkwood	37	902	402	136	266	167	43	124	1721	1073	648	1319
Rydalvale	39	33	85	75	10	35	30	5	376	16	16	291
Rondspring	44	639	168	105	63	60	30	30	1331	1024	307	1163
Phoenix	44	1261	268	104	164	109	27	82	1581	1024	557	1313

OD : oven dry* * TV : threshold value* *†NEAK : Non-exchangeable available potassium*

between 5 to 6 mg K per kg soil was released for a decline of 1 ppm in the soil test value.

Nitric acid method

For sands and medium textured soils the change in the nitric acid test value almost quantitatively predicted the amount of available K, while for the heavier textured soils, although far better than the ammonium acetate and calcium chloride tests, available K was still underestimated by a factor of nearly two.

Calcium chloride method

This test would seem to have little value in predicting reserves of available K. However, as far as the labile pool is concerned it appeared from the threshold values for calcium chloride in Table 2, that there would be less than about 30 mg K/kg present in the soil before a response to applied K could be expected. It was not possible, however to predict how long a particular soil would take to reach this level. For example, 639 mg K were removed from the Rondspring clay before the initial calcium chloride value of 60 ppm K was reduced to 30 ppm. On the other hand, only 134 mg K were taken up from Cartref topsoil before the initial value of 116 ppm K was reduced to 28 ppm. It is possible that the calcium chloride test could be of use in indicating K deficiency in the field because of the similarity of the calcium chloride values for the majority of the soils, at the threshold or response point.

Potassium balance sheet

The balance sheet presented in Table 4 following a lengthy period of cropping shows that for all soils, with the exception of the Clansthal and Fernwood sands, considerably more potassium was removed than was applied, even in most of the K2 treated soils where a plentiful supply of K fertilizer was added after each harvest. The amount of exchangeable K in all cropped soils for all treatments (except Rydalvale K2) had fallen to well below that determined initially. Only a relatively small amount (0.3-6.2%) of the total soil K was present initially in the exchangeable form. It would appear that most of the potassium must be present in forms which are not available to the plant since maximum crop removal shown in Table 4 represents only 13.3% of the total K.

The relative size of the non-exchangeable available pool K can be estimated for each soil from the results in Table 4, if this pool is assumed to be in equilibrium with exchangeable K, and any release from primary sources is ignored. The values obtained using the K0 treatments are shown in Table 5 and represent the ability of a particular soil to buffer any changes in the exchangeable K level. There was considerable variation in the size of this pool, the percentage of non-exchangeable available K ranging from 29 for the Clansthal sand to 670 for the Phoenix soil. In the Rondspring soil from Swaziland there was also no shortage of available potassium which suggest that the low level K/high soil K anomaly observed on 5 month-old cane grown on this soil could well

TABLE 3. The relationship between soil texture, threshold value and the ability of the soil test to predict potassium availability

Textural category	NH_4Ac K mean at TV ppm	* Mean K uptake / Mean Δ K (NH_4Ac) mg/kg	$CaCl_2$ K mean at TV ppm	* Mean K uptake / Mean Δ K ($CaCl_2$) mg/kg	HNO_3 K mean at TV ppm	* Mean K uptake / Mean Δ K (HNO_3) mg/kg
<16% clay	36	1.19	25	1.60	207	1.09
16035% clay	63	1.46	24	1.93	516	1.12
>35% clay	105	5.64	33	11.76	870	1.86

* *Indicates availability of K per unit change in soil test value above the threshold value (based on values in Table 2)*

be due to some physiological blocking mechanism, rather than an actual nutritional deficiency.

Non-exchangeable reserves of potassium (NEAK)

This term refers to the difference between the initial nitric acid and exchangeable K (ammonium acetate) values. Using the three textural categories already described, the average NEAK values determined from the data in Table 2 are as follows:

less than 16% clay	175 ppm (254)
16-35% clay	464 ppm (607)
more than 35% clay	1022 ppm (1544)

The comparable nitric acid values are shown in brackets. These figures indicate that soils with more than 35% clay are likely to have large reserves of non-exchangeable K some of which they are able to supply for a long period to the crop. The fact that crops removed considerably more potassium from the Phoenix, Milkwood and Rondspring soils (Table 4) than could be accounted for by differences in exchangeable K supports this contention. The Rydalvale soil which also has a high clay content could normally have been expected to have had large reserves of NEAK but the particular soil used had been continuously cropped to sugarcane since 1939 without the addition of K fertilizer. It was included, as was the Shorrocks series soil, primarily to determine the plant available reserves of K remaining in the soil. The data in Table 2 confirm that these had been reduced to a very low level, only 33 and 50 mg K being removed by the plant in the Rydalvale and Shorrocks soils, respectively, before the threshold value was attained.

Haysom[6] suggested that the NEAK value could provide an excellent stable site characteristic for the long-term potassium supplying ability of the soil. In the Mackay cane growing area of Australia, nitric acid extractable K values are used as soil test criteria by the Bureau's Fertilizer Advisory Service, as shown below:

HNO_3 soil K (ppm)	Category
less than 310	low
310-585	medium
586-975	high
more than 975	very high

Chapman[4] found that both the nitric acid and NEAK values gave better correlations with responses to K fertilizer than did exchangeable values.

Potassium measurement and plant uptake

A highly significant correlation was found between total uptake of K by the plant and the initial amounts of nitric acid soluble K ($r = 0.953$) and

TABLE 4. Potassium balance sheet calculated from pot experiment results after continuous cropping

Soil Series	Initial soil level		Exch-K after cropping (ppm)			Net mg K removed/kg soil			Crop removal (KO)
	Total K ppm	Exch-K ppm	K0	K1	K2	K0	K1	K2	as % of total K
Fernwood	610	34	4	3	16	43	40	1	7.0
Cartref (T)	12800	147	7	9	40	260	258	112	2.0
Cartref (S)	16990	52	15	16	21	105	101	84	0.6
Clansthal	1340	83	8	5	13	97	82	73	7.2
Waldene	9900	145	25	25	35	232	221	176	2.3
Shorrocks	3350	92	19	20	34	220	214	139	6.6
Tambankulu	2680	92	37	35	47	215	194	120	7.5
Glendale	15275	244	49	49	82	359	349	221	2.4
Milkwood	10150	402	63	54	112	1082	1080	539	10.7
Rydalvale	1990	85	23	24	95	188	164	22	9.4
Rondspring	5780	168	51	51	112	770	767	413	13.3
Phoenix	14280	268	93	115	196	1355	1365	679	9.1

TABLE 5. Estimates of non-exchangeable available potassium following continuous cropping

Soil series	Decline in Exch-K from initial value ppm	Crop uptake of K ppm	Relative amount (%) non-exch avail K
Fernwood	30	43	*43
Cartref (T)	127	260	*105
Cartref (S)	37	105	*184
Clansthal	75	97	*29
Waldene	120	232	93
Shorrocks	73	220	*123
Tambankulu	55	215	*291
Glendale	195	359	84
Milkwood	339	1082	219
Rydalvale	62	188	*203
Rondspring	117	770	558
Phoenix	175	1358	670

* *Soils cropped to nutrient exhaustion*

exchangeable K as measured by ammonium acetate (r = 0.834) (Figures 5 and 6). However, the time and equipment required for digestion with boiling nitric acid, when dealing with a large number of samples on a routine basis, tends to limit the practical value of this method. Further, the data in Table 3 indicate that there would probably be little advantage in using the nitric acid method in preference to the exchangeable K test for advisory purposes on light to medium textured soils, as the latter method fairly closely predicts K availability in these categories. The NEAK value could be used to advantage on heavy textured soils, however, as it provides a better measure, than does exchangeable K alone, of the ability of these soils to supply potassium on a long term basis.

The close correlation found between clay content and soil K threshold value in the glasshouse experiment implies that the single threshold value currently used to predict K fertilizer requirement in the South African sugar industry, is inadequate. Using the three textural categories discussed previously, average exchangeable K values at threshold were as follows:

less than 16% clay	36 ppm
16-35% clay	63 ppm
more than 35% clay	115 ppm (excluding Rydalvale soil)

From this it would appear that for sandy soils at least, a threshold value well below the 112 ppm K presently used would be more appropriate. On heavy soils though, there are indications that a threshold value higher than that currently used would be required. Mengel, in a private communication, states that K content expressed as mg K/100 g soil, particularly for soils rich in 2:1 clay minerals, should be somewhat higher than the percentage of clay. This means that if a soil has a clay content of 35% the exchangeable K value should be at least 350 ppm, which is well above that found in most of our soils. In the light of this information revised K fertilizer recommendations for the sugar industry are being prepared.

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DISPONIBILIDAD DE POTASIO EN SUELOS DE LA ZONA CAÑERA DE SUD AFRICA

R. A. Wood y J. R. Burrows

RESUMEN

El potasio del suelo segun fue analizado mediante varios procedimientos de extración se comparó con el potasio disponible determinado durante la cosecha contínua de ballico y sorgo en tiestos en una amplia gama de suelos de la zona cañera de Sud Africa. Tanto para los métodos de potasio extraíble con acetato de amonio como con ácido nítrico, hubo una correlación positiva altamente significativa (r = 0.80) entre el contenido de arcilla y el valor umbral. Se concluyó que el solo valor umbral corrientemente en uso, para predecir los requerimientos de abono potásico en Sud Africa es inadecuado. Hubo poca ventaja en utilizar con el propósito de hacer recomendación el método de ácido nítrico en preferencia al actual método utilizado de acetato de amonio en suelos de textura liviana a mediana, ya que el último método predice estrechamente la disponibilidad del potasio en estas categorías. Sin embargo, el valor NEAK (K ácido nítrico-K acetato de amonio) se pudiera utilizar ventajosamente en suelos de textura pesada, puesto que proporciona una mejor medida de la disponibilidad de estos suelos para suplir potasio a largo plazo.

RESPONSE OF ORGANO-TABLET FERTILIZER TO SUGARCANE GROWN ON SANDY GRAVEL SOIL

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ABSTRACT

Organo-tablet fertilizer containing nitrogen (N), phosphorus (P), and potassium (K), developed by Taiwan Sugar Research Institute has been evaluated for its effectiveness on the growth of sugarcane planted on gravel and sand soil.

Field experiments indicated that tablet fertilizers increased cane yield significantly. Sugarcane yields in plots, where the fertilizers were split in two applications, were 17-29% higher than those of check plots where ammonium sulfate was applied six times.

With normal irrigation practices, tablet fertilizers can be identified and last for two to three months in gravel and sandy soils. Loss of plant nutrients by leaching was greatly reduced. Increases in N, P_2O_5 and K_2O uptake of sugarcane were 11-102%, 62-282% and 12-61%, respectively, with ammonium sulfate, superphosphate and potassium chloride as checks.

By using tablet fertilizers on gravel and sandy soil, the cost of fertilization was reduced and the cane yield was increased.

INTRODUCTION

Of the total 47,380 ha sugarcane fields owned by Taiwan Sugar Corporation (TSC), around 7,500 ha are sandy and gravel soils. The main limiting factor to sugarcane growth on these areas was their high transmissibility to waters and plant nutrients. Fertilizers, especially N, were usually split into 6-8 applications on those fields in order to reduce loss of nutrients. Slow release fertilizers such as CDU and SCU tested on the soils with sugarcane, have also been subject to leaching. The cost therefore was not competitive with conventional fertilizers.

A basic chemical theory of solubility, states that the larger the surface area of a solute, the higher is its water solubility. DeMent and Standford[1] reported that with higher water solubility, approximately twice as much potassium was leached from the larger (–6+9 mesh) than from the smaller particle size (– 35 mesh). That is, low solubility and coarser particle size reduced loss of potassium. Pritchett and Nolan[9] found that a high recovery of potassium was obtained from the large particles of KCL and KPP (a very long-chain potassium polyphosphate of formula,

$(KPO_3)_n$). On the other hand, DeMent, Terman and Bradford[2] showed that the effect of increasing the particle size is apparently different for KCP (potassium calcium pyrophosphate, $K_2CaP_2O_7$) and KPP. The immediate effectiveness of KCP and KPP declined noticeably with increase in particle size. But KCP compound did exhibit a fairly low rate of dissolution when added as coarse particles. Results of greenhouse experiments reported by Lehr, Engelstad and Brown[8] indicated that the relative effectiveness values, based on K uptake of first crop of corn for K_2SO_4 were 100 and 115 for fine (— 100 mesh) and coarse (—6+14 mesh) particles, respectively. In a greenhouse study in Israel, Lachover and Feldhay[5] and Hagin[3] found that KPP was as effective as KCl and K_2SO_4, regardless of particle size.

Effect of fertilizer particle size on P migration was studied by Lawton and Vomocil[6]. The main effect of using the larger tablet was to increase the size of the zone of influence. This was shown when the ½-inch tablet developed a zone of influence about 7.5 times greater in volume than the zone of influence of the ¼-inch tablet. Radiation counts on the two tablets at the end of the trial indicated that larger tablet (½-inch) contained 18.3% of its original p^{32} content, while the smaller tablet (¼-inch) contained 15.7%.

Unpublished data from field experiments conducted in Taiwan revealed that rice yields from plot treated with mudball, (urea coated with clay soil) showed 15% increase over check (urea only) in paddy fields.

In order to reduce the number of fertilization and nutrients loss on sandy gravel soil, this study was designed to develope a delayed-release fertilizer by incorporating chemical fertilizers with organic by-products from sugar mill to make organo-tablet fertilizer in various particle sizes containing nitrogen, phosphorus and potassium. Laboratory tests, pot tests and field experiments were simultaneously conducted to verify its response to sugarcane on sandy gravel soil.

MATERIALS AND METHODS

1. *Materials and processes used for making tablet fertilizer*

Three major plant nutrient of N,P, and K, were first mixed with dried and crushed organic materials such as filter cake, bagasse, active sludge (from pulp factory) and solid hog wastes at a proportion 4.4 N: 1 P_2O_5: 2 K_2O which is commonly used on TSC's farms. The mixed fertilizer material was then pressed with sizes (Fig. 1). The size, density and coating of the tablet fertilizer have been used as a measure to adjust its rate of dissolution in gravel sand soil.

2. *Leaching test*

(1) Fetilizers were placed in leaching column with 3.0 cm inner diameter, and 25.5 cm in length prepacked with sandy gravel soil and then leached with a certain amount of water equivalent to 60 mm effective rainfall at a rate of 30 mm/hr. The contents of N,P, and K in the leacheate were analyzed by using the following methods[4].

N: Magnesium oxide, Kjeldahl method, AOAC.
P: Molybdovandophosphate method, AOAC.
K: Flame photometric method, AOAC.

(2) Rock phosphate was treated with H_2SO_4, and tagged with p^{32} to make radioactive superphosphate. Then it was mixed with N and K. Half the amount of tagged superphosphate was pressed into 16 mm tablet

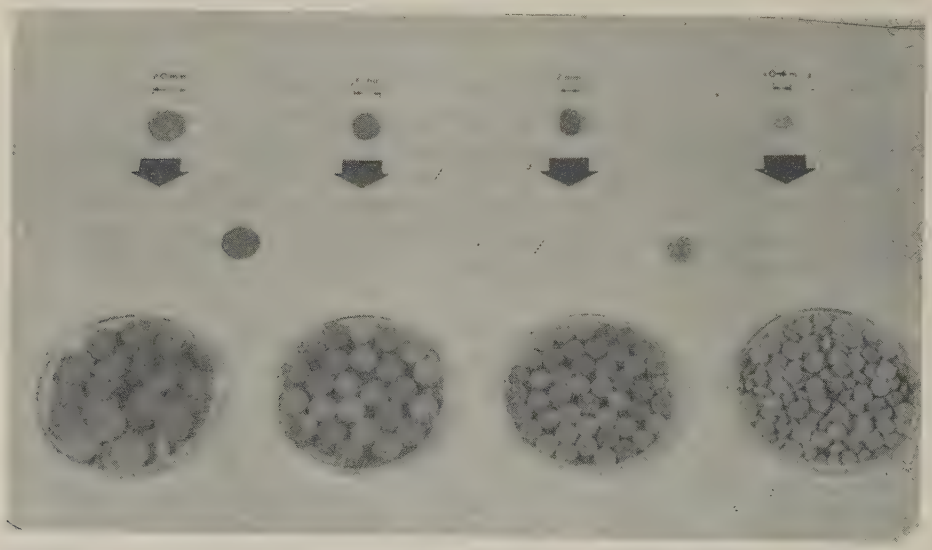


FIGURE 1. Organo-tablet fertilizers.

fertilizer under the condition already described while the other half remained in granulated form. Each tagged tablet fertilizer contains 40 uc p^{32}. Comparison of the movement of P between tagged tablet fertilizer and tagged granulated fertilizer was made in a column, 50 cm in length and 5.2 cm in inner diameter, prepacked with gravel sand soil taken from Liukuaitso farm. Carefully packed soil column was pre-saturated with 500 ml water before equal amount of p^{32} tablet and granulated fertilizers were placed into separate columns at the depth of 3 cm. Soil of the column was covered with filter paper and leached with 4700 ml water (equivalent to the amount of 2300 mm water needed for one autumn cane crop in Pingtung area) at a constant rate of 60 mm/hr. The soil column was then divided into two halves after the completion of leaching and their counting rates were detected with Geiger counter by using linear scanning method.

3. Pot tests

Gravel coarse sand taken from Likong river bed was used for pot tests (cement pot of 60 cm in diameter and 60 cm in height). Eleven to sixteen different kinds of fertilizers (see Fig. 5,6,7) were applied at the rate of 220 N: 50 P_2O_5: 200

K_2O kg/ha. Two F177 cuttings were planted in March 20, 1977 and harvested in Sept. 20, 1978 for each treatment which was replicated two times. All fertilizers were used in one application except for check pot of which ammonium sulfate was applied in three applications.

4. Field experiments

Field experiments on two autumn crops of cane planted in sandy gravel soil have been conducted in TSC's farms located in Pingtung sugar mill. On Liukuaitso farm, F170 was planted in Aug. 20, 1977 and harvested in Nov. 24, 1978. On Ailiaochi farm, planting and harvesting of F156 were made in Sept. 23, 1977 and Dec. 18, 1978, respectively. Randomized complete block design was laid out and replicated 5 times. Every plot had 8 rows which were 1.25 km apart and 8 m long each. Fertilizers applied at the rates of N: 220, P_2O_5: 50, and K_2O: 100 kg/ha for each plot were treated as follows:

1. Check, ammonium sulfate 6 applications.*
2. Tablet fertilizer A, 12 mm, 3 application.**
3. " 12 mm, 2 "
4. " 12 mm, 1 "
5. " 16 mm, 3 "
6. " 16 mm, 2 "
7. " 16 mm, 1 "
8. " 20 mm, 3 "
9. " 20 mm, 2 "
10. " 20 mm, 1 "

*On check plot, phosphorus and potassium were applied in 1 and 2 applications, respectively.

**On treated plots, all P and K were applied as basal application, the second and third applications were N only.

RESULTS AND DISCUSSION

1. Leaching test

Laboratory tests indicated that, with a given amount of water the loss of plant nutrients by leaching was greatly reduced with the use of tablet fertilizers as compared with commercial fertilizers commonly used on TSC's farms. Fig. 2 demonstrated that the percentage on N leached under conditions of 60 mm effective rainfall of tablet fertilizer was only 5%. Leaching from compound fertilizer No. 1 (20-5-10) and No. 2 and ammonium sulfate was up to around 50%. The amount of P_2O_5 leached out was only 0.4% of the original amount from tablet fertilizer, for superphosphate and compound fertilizer No. 2, 15.1% and 6.3%, respectively were lost through leaching. Twenty-seven to thirty nine percent of original K_2O from KCl and compound fertilizers was lost but only 5% K_2O was lost from the tablet fertilizer. Failure to detect P_2O_5 in the leacheate of compound fertilizer No. 1 could be attributed to the lower water solubility of P. In other words, an amount of

60 mm water might not be enough to leach P_2O_5 out.

The movement of P in tagged fertilizer in sandy gravel soil is shown in Fig. 3. The counts per minute (CPM) in the upper 0-6 cm layer for tablet fertilizer was much higher than that of granulated fertilizer. In the 6-8 cm layer, the radiation counts in the tablet fertilizer column was still higher than in the column of granulated fertilizer. However, the CPM curves of these two fertilizers matched each other in depths of 18-40 cm. In 50 cm depths, the CMP curves showed deviations indicating the superiority of tablet fertilizer over granulated fertlizer in reducing P losses. Higher CPM in the tablet fertilizer column illustrated the lower rate of P movement in sandy gravel soil. The lower total radiation counts in the granulated fertilizer column implied that quite an amount of p^{32} was leached down to more than 50 cm deep into the leacheate when it was applied on sandy gravel soil.

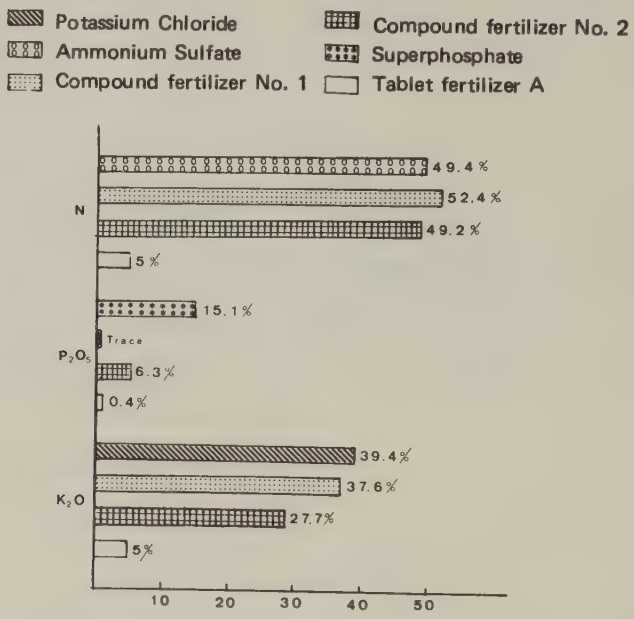


FIGURE 2. Percentage of N, P_2O_5 and K_2O leached out under the condition equivalent to 60 mm effective rainfall.

2. Nutrient uptake and yield of sugarcane in pot test

Response of sugarcane to tablet fertilizer was significant both in terms of cane yield and nutrient uptake in pot test. Fig. 4 indicated that cane yields (at age of 6 months) from all tablet fertilizer treatments (with one application), increased from 12 to 100% over the control in which ammonium sulfate was applied three times. Little difference in the increase of cane yield from the different fertilizer sizes and the control treatment was obtained. It averaged 71%, 69% and 62% for 12 mm, 16 mm and 20 mm respectively.

Plant nutrient uptake of sugarcane was greatly increased in tablet fertilizer

pots due to the decrease in leaching loss (Figs. 5,6 and 7). The larger the size of tablet fertilizer, the lesser was the N uptake by sugarcane. Increases in N uptake over the control averaged 59.3%, 58.3% and 34.3% for 12 mm, 16 mm and 20 mm tablet fertilizers, respectively.

Effect of the size of fertilizer on P_2O_5 and K_2O uptake was quite different from N uptake. The average P_2O_5 and K_2O uptakes by sugarcane were more

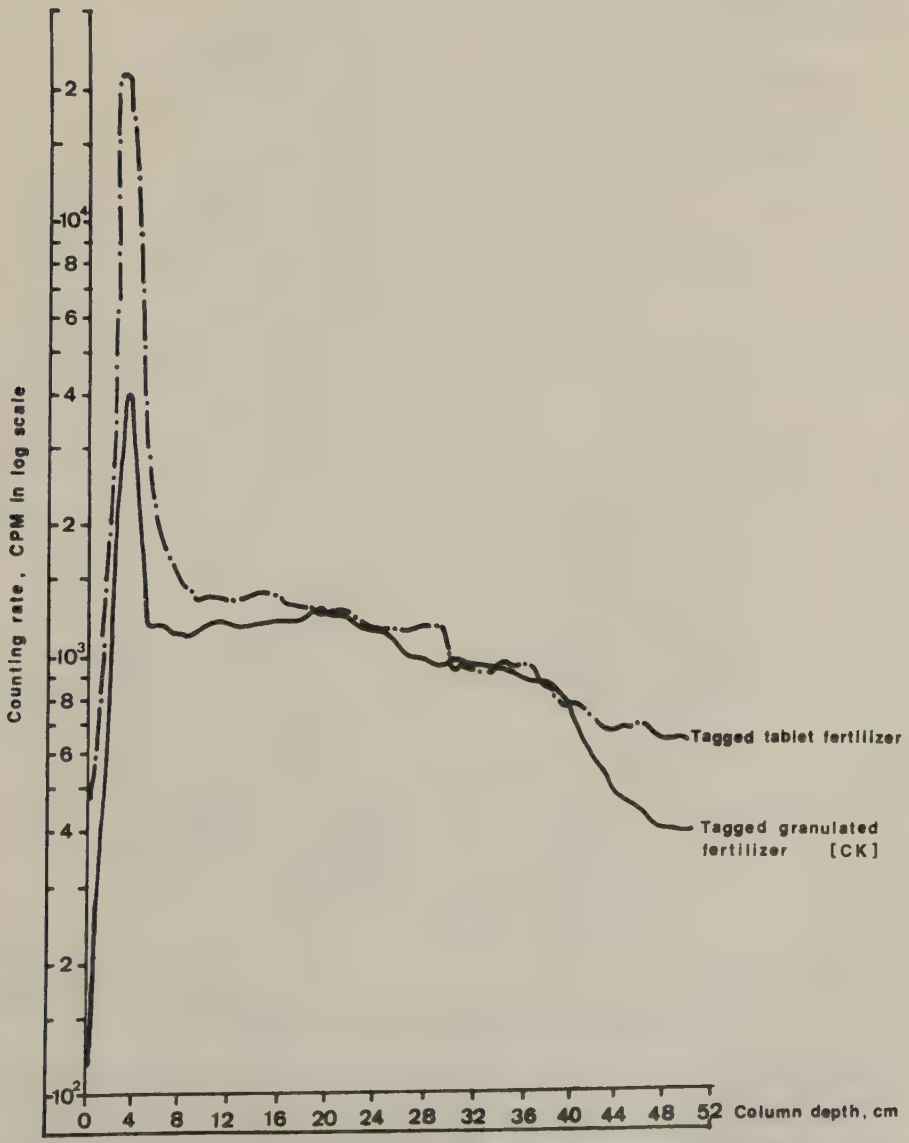


FIGURE 3. The movement of P in tagged tablet and granulated fertilizers in soil column.

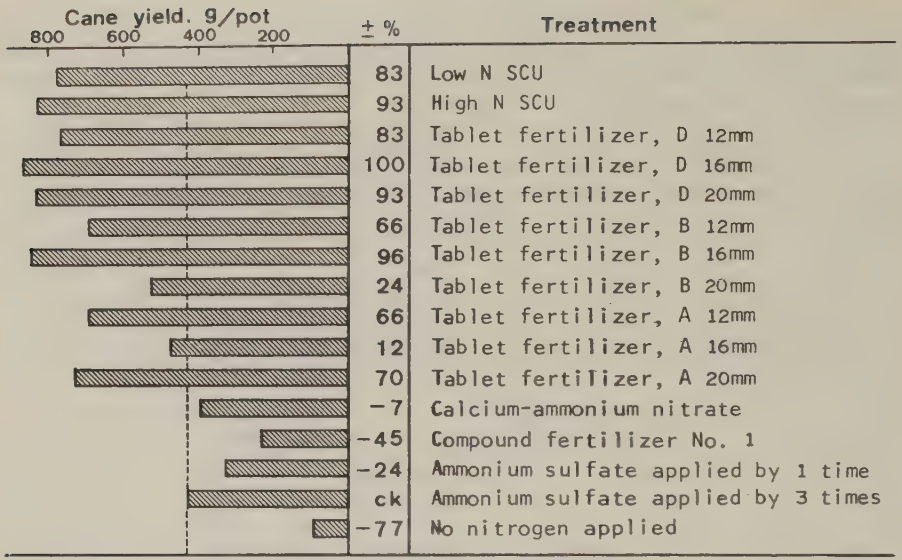

Cane yield, g/pot
800 600 400 200
± %
Treatment
83 Low N SCU
93 High N SCU
83 Tablet fertilizer, D 12mm
100 Tablet fertilizer, D 16mm
93 Tablet fertilizer, D 20mm
66 Tablet fertilizer, B 12mm
96 Tablet fertilizer, B 16mm
24 Tablet fertilizer, B 20mm
66 Tablet fertilizer, A 12mm
12 Tablet fertilizer, A 16mm
70 Tablet fertilizer, A 20mm
−7 Calcium-ammonium nitrate
−45 Compound fertilizer No. 1
−24 Ammonium sulfate applied by 1 time
ck Ammonium sulfate applied by 3 times
−77 No nitrogen applied

FIGURE 4. Cane yield in relation to various sources of fertilizers applied (pot test, cane age of 6 months).

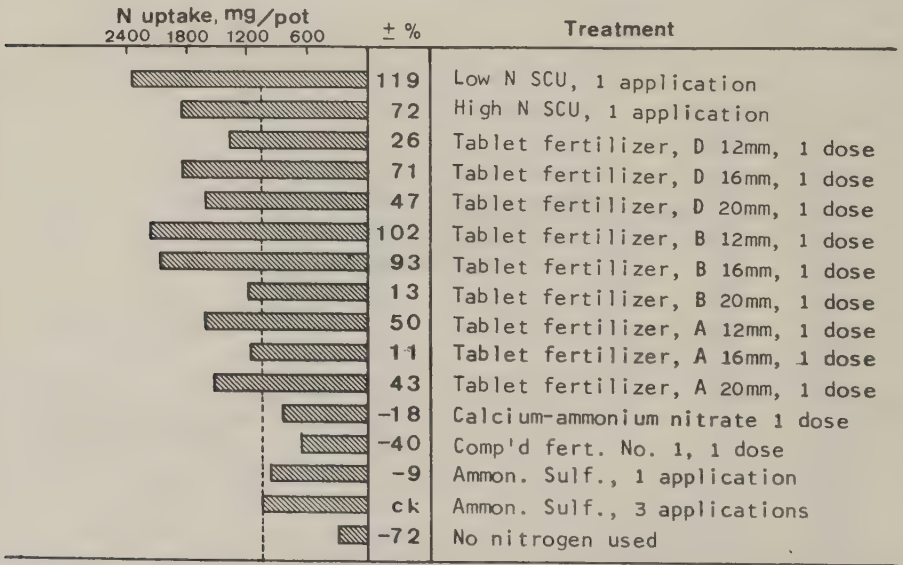

N uptake, mg/pot
2400 1800 1200 600
± %
Treatment
119 Low N SCU, 1 application
72 High N SCU, 1 application
26 Tablet fertilizer, D 12mm, 1 dose
71 Tablet fertilizer, D 16mm, 1 dose
47 Tablet fertilizer, D 20mm, 1 dose
102 Tablet fertilizer, B 12mm, 1 dose
93 Tablet fertilizer, B 16mm, 1 dose
13 Tablet fertilizer, B 20mm, 1 dose
50 Tablet fertilizer, A 12mm, 1 dose
11 Tablet fertilizer, A 16mm, 1 dose
43 Tablet fertilizer, A 20mm, 1 dose
−18 Calcium-ammonium nitrate 1 dose
−40 Comp'd fert. No. 1, 1 dose
−9 Ammon. Sulf., 1 application
ck Ammon. Sulf., 3 applications
−72 No nitrogen used

FIGURE 5. Nitrogen uptake by sugarcane in relation to various sources of fertilizers applied (pot test, cane age of 6 months)

pronounced for 20 mm tablet fertilizer than for the smaller ones. Phosphorus is regarded as a relative immobile element in the soil. In the pot test with such a limited soil volume, the effect of large tablet fertilizer on the increase in the zone of influence of phosphorus would be higher than that of the small tablets (Lawton and Vomocil[6]). The % P_2O_5 uptake by sugarcane from the different size of tablet

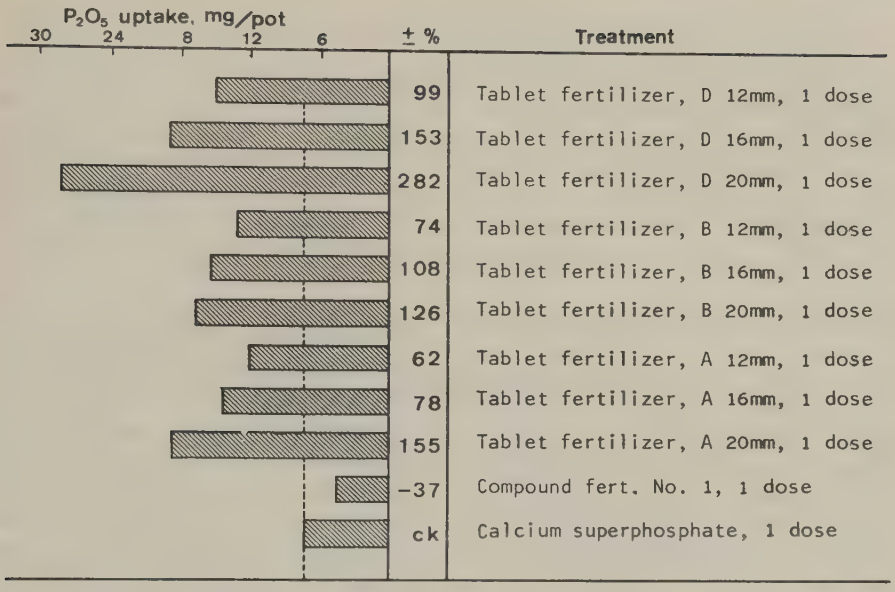

P_2O_5 uptake, mg/pot
30
24
8
12
6
± %
Treatment
99 Tablet fertilizer, D 12mm, 1 dose
153 Tablet fertilizer, D 16mm, 1 dose
282 Tablet fertilizer, D 20mm, 1 dose
74 Tablet fertilizer, B 12mm, 1 dose
108 Tablet fertilizer, B 16mm, 1 dose
126 Tablet fertilizer, B 20mm, 1 dose
62 Tablet fertilizer, A 12mm, 1 dose
78 Tablet fertilizer, A 16mm, 1 dose
155 Tablet fertilizer, A 20mm, 1 dose
−37 Compound fert. No. 1, 1 dose
ck Calcium superphosphate, 1 dose

FIGURE 6. Phosphorus uptake by sugarcane in relation to various sources of fertilizers applied (pot test, cane age of 6 months).

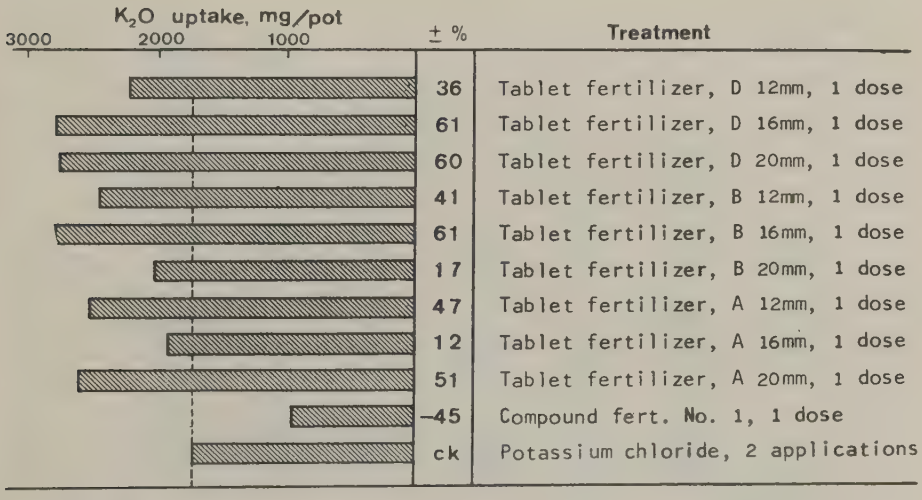

K_2O uptake, mg/pot
3000
2000
1000
± %
Treatment
36 Tablet fertilizer, D 12mm, 1 dose
61 Tablet fertilizer, D 16mm, 1 dose
60 Tablet fertilizer, D 20mm, 1 dose
41 Tablet fertilizer, B 12mm, 1 dose
61 Tablet fertilizer, B 16mm, 1 dose
17 Tablet fertilizer, B 20mm, 1 dose
47 Tablet fertilizer, A 12mm, 1 dose
12 Tablet fertilizer, A 16mm, 1 dose
51 Tablet fertilizer, A 20mm, 1 dose
−45 Compound fert. No. 1, 1 dose
ck Potassium chloride, 2 applications

FIGURE 7. Potassium uptake by sugarcane in relation to various sources of fertilizers applied (pot test, cane age of 6 months).

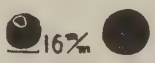
fertilizers over the check, averaged 78.3%, 113% and 18% for 12 mm, 16 mm, and 20 mm, respectively. K_2O uptake for 12 mm, 16 mm and 20 mm tablet fertilizer were 42.3%, 44.7% and 57%, respectively. The uptake of large amounts of plant nutrients by sugarcane in tablet fertilizer pots illustrated lower leaching loss of N, P and K than in conventional fertilizer pots.

3. Rate of decomposition of tablet fertilizer under field condition

Tablet fertilizer of 16 mm size was placed into sandy gravel soil at a depth of 15 cm (half way between the top of the ridge and furrow bottom) to test its decomposition rate under normal irrigation. Stages of decomposition of coated tablet fertilizers with 1% and 2% urea resin and uncoated tablet fertilizers are shown in Fig. 8. Tablet fertilizer coated with 2% urea resin could still be identified in the soil after a lapse of 4 months under field conditions of more than 200 mm of irrigation. Uncoated tablet fertilizer remained in a good condition for 2 months.

Table 1 shows the amount of nitrogen retained in tablet fertilizer resulting from heavy irrigation in pot tests. For the first 15-day interval, nearly 50% of the original total N remained in the tablet fertilizer after irrigation with 157 mm water. There was not much difference between results obtained from the coated and uncoated treatments. Apparently the rate of dissolution of N in gravel sandy soil applied with tablet fertilizers has been greatly delayed and improved as compared to that with conventional N containing fertilizers. After 30 days and 314 mm water irrigation, tablet fertilizer, either coated or uncoated, can retain more than 5% of its original N content. At the end of 45 days and 60 days, 0.8% to 2.8% N in tablet fertilizer can still be detected. This result indicated that with the use of tablet fertilizer, N supply to sugarcane could last for 60 days on sandy gravel soil.

Stages of decomposition of urea-resin coated organo tablet fertilizer under field condition



Treatment	Liu k'uai ts'o (sandy plot)			Ai liao ch'i (gravelly plot)		
	Month after application			Month after application		
	2 months	3 months	4 months	2 months	3 months	4 months
None coated (CK)						
1% U.R. coated (by wt)						
2% U.R. coated (by wt)						
Total amount of water irrigated (mm)	72	192	252	106	158	211

FIGURE 8. Stages of decomposition of tablet fertilizers under field condition.

4. Yield response to tablet fertilizer of sugarcane under field conditions.

TABLE 1. Nitrogen retention in tablet fertilizer under heavy irrigation (pot test)

16 mm tablet fertilizer	Days interval and N retained in %			
	15	30	45	60
2% urea resin coated	47.1	5.8	2.8	0.8
Uncoated	42.4	5.4	1.5	0.9

(a) Amount of water irrigated: 157 mm x 4 times = 628mm which is equivalent to the total amount of rainfall in Aug., Sept. and Oct. in Pingtung area.

(b) Soil used: Gravel coarse sand taken from Likong river bed.

On the sandy gravel soil of Liukuasitso farm, significant increases in cane yield ranging from 17% to 29% over the check treatment were obtained with 12 mm and 16 mm tablet fertilizer treatments made in 2 and 3 applications. In the plots of tablet fertilizers applied only once, cane yields were generally decreased by 5-18%. It was obviously due to the leaching effect resulting from a 259 mm rainfall which poured the next day after fertilization.

Of the three tablet fertilizer sizes, 12 mm gave the highest response in sugarcane yields and 20 mm gave the lowest. With equal rates of fertilizer used, the number of 12 mm tablet fertilizer should be greater than that of 20 mm size. This means that in the nutrients 12 mm tablet fertilizer would be more evenly distributed in the soil than those in the 20 mm size. In this study, 12 mm tablet fertilizer seemed to be better than any other tablet size. In general, the use of 12 mm tablet fertilizer split into two applications on sandy gravel soil not only increased autumn cane yield but also reduced the cost of four applications of fertilizers.

On Ailiaochi sandy gravel soil, response of sugarcane growth to tablet fertilizer was not significant as it was on Liukuaitso farm. However, cane yields from the tablet fertilizer treatment with 3 applications was still superior to check plot. The lack of yield response to tablet fertilizer in 1 and 2 applications was apparently due to severe soil variation among replications. Lee and Liao[7] reported that, in Pingtung sugarcane growing area, the distribution of gravel and sand varied greatly through the profile from one layer to the other even though they were only a few feet apart. With such a large quantity of gravel content up to more than 55% by weight distributed on Ailiaochi plot we found that the magnitude of difference in cane yield among replications may be up to sixfold.

CONCLUSIONS

Chemical fertilizers incorporated with organic by-products from sugar mills can be pressed into organo-tablet fertilizer of various sizes under a given pressure. Sugarcane yield responses to tablet fertilizer in 2 or 3 applications on sandy gravel soils was significant. Sugarcane responses was also affected by the size and density of tablet fertilizers. Tablet fertilizers of 12 mm size, seemed to be suitable for sugarcane. Under normal irrigation practice, tablet fertilizers can be identified and

last for two to three months to suppy sugarcane with its nutrient needs. A significant reduction in the loss of plant nutrients in the soil and an increase in nutrient uptake by sugarcane were evident in this study.

TABLE 2. Response of autumn cane yield to tablet fertilizer application, (t/ha)

	Treatment	Liukuaitso farm			Ailiaochi farm		
		Yield	Index	Sign.	Yield	Index	Sign.
(1)	Ammonium sulfate, 6 applications (CK)	92.9	100		100.3	100	
(2)	12 mm tablet fertilizer A, 3 applications	115.7	125	***	102.0	102	NS
(3)	12 mm " , 2 "	120.2	129	***	94.1	94	"
(4)	12 mm " , 1 "	85.3	92		89.8	89	"
(5)	16 mm " , 3 "	109.7	118	**	106.0	106	"
(6)	16 mm " , 2 "	109.1	117	*	94.8	95	"
(7)	16 mm " , 1 "	76.5	82	—	92.0	92	"
(8)	20 mm " , 3 "	107.7	116	*	104.3	104	"
(9)	20 mm " , 2 "	86.7	93		98.0	98	"
(10)	20 mm " , 1 "	88.4	95		90.5	90	"

*LSD: 22.55 t/ha (1%, ***); 16.8 t/ha (5%, **).*

(a) Liukualtso farm field No. 36: pH 8.3, 85% of the <2 mm fraction are sand, 30-40% of the surface soil are gravel (>2 mm, by weight).

(b) Ailiaochi farm, field No. 35: pH 7.9, surface soil contains grave (>2 mm) greater than 55% by weight.

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RESPUESTA A LA CAÑA DE AZUCAR EN SUELO CASCAJOSO ARENOSO A FERTILIZANTE ORGANO-PELETIZADO

Wang Chwan-Chau, Chan Yuan-yu, Chang Chin-hua y Chang Shun-rong

RESUMEN

Se evaluó fertilizante organo-peletizado conteniendo N, P, y K desarrollado por el Instituto de Investigación de Azúcar de Taiwan en cuanto a su efectividad para el crecimiento de caña de azucar en suelo cascajoso arenoso.

Experimentos de campo indicaron que los rendimientos de caña aumentaron significativamente a respuestas de fertilizante peletizado.

Los rendimientos de caña de azúcar con fertilizante peletizado en dos aplicaciones fueron de 17-29% mayores que el testigo en que se aplicó sulfato de amonio seis veces.

Bajo practicas normales de riego, el abono peletizado se puede identificar y dura dos o tres meses en suelo cascajoso arenoso de esta manera liberando los fitonutrientes para el cultivo de la caña. La pérdida de fitonutrientes por lixiviacion fué grandemente reducida. Los aumentos en absorción de N, P_2O_5 y K_2O por la caña variaron de 11-102%, 62-282% y 12-61%, respectivamente, en relación a sulfato de amonio, superfosfato y cloruro de potasio como testigos.

El uso de fertilizante peletizado en suelo cascajoso arenoso permite lograr tanto una economia en el costo del fertilizante como un aumento en el rendimiento de caña.

EFFECT OF WATER TABLE DEPTH ON CRITICAL SUGARCANE SALT CONCENTRATION LEVEL

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Trujillo, Peru

ABSTRACT

In saline fields with superficial water-table (80 to 110 cm) good yields could be obtained with conductivity as high as 8 mmhos/cm. On the other hand, with deep water-table (under 2 m) conductivity of only 2 mmhos/cm was enough to lower the yield to about 15%. It was also found that in saline-sodic soil, besides the harmful effect of salts, sodium also exert yield depressive effects. The dual negative effect reduce the critical level of salts to as low as 1.6 to 2.0 mmhos/cm.

INTRODUCTION

The effects of soil salinity on sugarcane production have been studied extensively. Different critical levels of salinity exists for different cultivars weather conditions, kind of salts and different soils management.

Robinson and Worker[20] indicated that a conductivity slightly greater than 4.2 mmhos/cm would reduce the yield by 50%. In Taiwan, Shen and Tung (in Liu[12]) and in Puerto Rico, Liu[12], reported that sugarcane varieties differed greatly in salt tolerance. In Iran, Shoji and Sund[22] concluded that soil conductivity of 4 mmhos/cm was the threshold, above which the growth of sugarcane was drastically reduced. In Puerto Rico, Liu reported that in the susceptible varieties of sugarcane, salt injuries developed first on sugarcane in soil with a salt conductivity at 5.4 mmhos/cm. In Natal, Von der Meden (in Mehrad[13]) reported that at soil conductivity below 2 mmhos/cm growth was not affected; between 2 to 4 mmhos/cm growth was reduced, while at conductivities above 4 mmhos/cm yields were seriously affected. Bernstein *et al*[2] studied salt tolerance of NCo varieties and found 25% yield reduction at conductivities of about 5 mmhos/cm. In South Africa it was found that at conductivities above 4 mmhos growth were seriously affected. From 2 to 4, mmhos growth was reduced and it was a good growth with less than 2 mmhos/cm (South African Sugar Association[23]). Leverington in Australia (in Fogliata and Aso[6]), working with Pindar and NCo 310 varieties, found that the growth of sugarcane was satisfactory even at 3.93 mmhos/cm. In Iraq, (Gowing and Rozeff[9]) on the basis of earlier experience, determined

leaching. Syed and El-Swaify[25] found that the tolerance of H50-7209 exceeds that of NCo-310 as dry matter yield reduction for the two cultivars were 23 and 45% at 8 mmhos salinity respectively. Sund and Clements[24] indicated that a soil conductivity of about 3 mmhos is the threshold above which fields of most varieties of sugarcane are severely reduced. Of great interest is the apparent indifference of NCo 376 to moderate saline conditions.

As can be seen, the degree of damage in sugarcane crop change in a wide range of salinity. As such it is very complicated to determine a critical level for different conditions of cultivars, weather, kind of salts and soils management.

As to water table depth effect on sugarcane yield, the different workers did not even agree. Pao and Hung[11] in Juang and Uehara shows pots experiments in which NCo 310 was grown with water table levels held at 50, 100 and 150cm with a fluctuating field water table as a check. The weight of roots and the sugar content of the cane grown over a water table depth of 150 cm were significantly higher than for the other treatments. On the other hand, Fogliata *et al*[7] observed under field conditions that the cane had a good performance with 1.6 to 2.2 water table depth, while it performed at 0.8 to 1.6 m. Wilkins and Ateshian[32] found that for Berbice Fronthand clays, the optimum depth of ground water table, allowing 45 cm for root zone, is about 1.45 meter. Gosnell[8] found that the 25 cm water table caused large reductions in cane yield, the 50 cm water table gave intermediate results, and no differences in growth were observed between 75, 100 and 125 water tables, which gave the best results. Perez *et al*[14] found that in PR 980 variety the treatment with ground water at 120 cm produced the best yield of cane and sugar (around 48% more than the 30-cm treatment). However in PR 1028 and PR 1059 varieties there was no significant difference between treatments. Juang and Uehara[11] reported that the 80 cm water table depth resulted in a significantly higher yield than the 50 and 30 cm depths in the sandy loam soil. In the clay, loam the 80 cm depth missed significance at the 5% level by small margin. Risseeuw[17] indicated that the negative influence of the ground water table on cane and recoverable sugar yield is important if ground water depth is above 25 cm from the bottom of the furrow. In a study about statistical ground water levels realized in cylinders, Bazan[1] found that the water table at 60 cm depth was the best (exceeding in yield 20, 40 and 80 cm). Faber *et al*[4] reported a problem in drainage when the ground water levels are less than 75 cm depth. He also indicated that there are yield reduction with ground water levels less of 1.5 m a month later of a normal irrigation. Sevilla *et al*[21] concluded that when the water table levels are maintained under 140 cm depth sugarcane yields obtained are the maximum.

The present study was conducted to determine the critical level of salts that affect sugarcane yield, under saline and saline-sodic soils conditions. Furthermore, the salinity critical level was integrated with the ground water depth to study whether the water table depth has an important function in the sugarcane response to the different concentration of soil salts.

MATERIALS AND METHODS

The experiment was carried out under field conditions in the Peruvian arid coast, using the sugarcane cultivar, H32-8560.

The soils in the zone are alluvial (entisols), with profile recently developed and without well-defined horizons, poor in N, but rich in P and K. Some differential characteristics for the 3 valleys studied are presented in Table 1.

TABLE 1. Characteristics of studied fields

	Fields		
	Los Angeles	Santa Rosa	Jiron 3-C
Location (valley)	Chancay-Lambayeque	Zaña	Chicama
Cutting or planting date	May, 1974	September, 1972	February, 1977
Crop	Plant	Plant-Ratoon	Ratoon
Annual precip. (mm)	28	34	20
Mean annual evapor. (mm/day)	4.6	5.8	4.5
Average annual temperat. (°C)	21.9	22.2	20.1
Plots area (m^2)	1,800	2,200-1,100[x]	3
Number of plots	50	20 - 40[x]	24
Soil samples/plot	10	7	1
Water table depth (cm)	> 200	40 to 150	80 to 110
Salin. range in water table (mmhos/cm)	5.5 to 20.0	3.0 to 30.0	5.0 to 14.0
Water table salts predominant	Na, Mg, Cl and SO_4	Na, Mg, Cl and HCO_3	Na, Mg, SO_4 and Cl
Soil texture	Clay loam	Sandy loam	Loam
Saturation %	52	26	48
Paste pH	8.0	8.6	8.2
Soluble CO_3^{2-} meq/100 g	0	0.006	0
Exchangeable sodium %	11.4	20.1	8.0
$CaCO_3$ %	4.5	6.7	4.4
Organic matter %	1.6	1.1	1.5
Total nitrogen %	0.076	0.059	0.073
C/N ratio	13.6	11.2	13.3
Available N kg/ha	38	33	38
Available P_2O_5 kg/ha[xx]	3929	1998	2628
Available K_2O kg/ha	1871	2461	1356
Available Ca kg/ha	19,528	10,442	13,403
Soil classification	Saline	Saline-sodic	Saline

x Plant and ratoon cane, respectively
xx Egner-Riehm method

In Los Angeles, field, the experimental plots were delimited by previous soil analysis, but in the Santa Rosa and Jiron 3-C fields the plots delimitation was made by grouping areas uniform on the following characteristics: a) areas where the cane did not sprout, b) those with very stunted or scarcely sprouted cane, c) those with stunted cane, d) areas with middling growth, e) areas with vigorous growth, and f) areas with full-sized vigorous sugarcane. This system also has been used in South Africa by the South African Sugar Association[23].

At harvest, all yield per plot taken in was in t/ha. Likewise in each plot samples of burned cane were taken to evaluate its quality and concentration of recoverable sugar.

To assure the representation of soil salinity of each plot studied, a high number of samples were taken (Table 1) with exception of the Jiron 3-C field where the salinity of each plot was represented only by one sample by depth.

Soils in each plot were sampled at 3 depths from the bottom of the furrow: 0-30, 30-60 and 60-90 cm. Samples of the same depth were joined to form one complex sample which represent the plot and analyzed in the laboratory.

To compare the four experiments, the yield of cane/ha was expressed as a relative % in terms of higher yield. These relative % were correlated with the soil salinity in the 0-60 cm layer. The origin of curves of each one of the regression equations, begun in different percentages, so transformations were done to make uniform the beginning of all equations (in the range of salinity observed) in 100%.

RESULTS AND DISCUSSION

Critical Levels of Salinity

Highly significant correlation between relative yield of cane and soil salinity in the four experiments evaluated was found. Regression equations with their respective values of R and F tests are presented in Table 2.

Bernstein (in Reeve and Fireman[16]) expressed the salt tolerance in terms of 15% yield reduction and the U.S. Salinity Laboratory[26] considered the 50% yield reduction. In the present discussion 15% was considered permissible critical level.

In Fig. 1 it can be seen that ratoon cane of Santa Rosa field was most affected by salinity, with 1.6 mmhos/cm as critical level and a 50% yield decrease with 3.6 mmhos/cm. This indicates that under some conditions only a small variation of salinity is necessary (2.0 mmhos/cm in this case) to produce highly significant differences in sugarcane (Pinna[15]). Cane plant of Santa

TABLE 2. Regression equations for relative yield and soil salinity, including F value of the analysis of variance and correlation coefficient (R) (For Santa Rosa field plant cane (P) and ratoon cane, Los Angeles plant cane and Jiron 3-C ratoon cane).

Field	Regression equation	R	F
Santa Rosa (P)	$Y = 93.4231 - 13.6738X + 0.5225X^2$	0.71^{xx}	xx
Santa Rosa	$Y = 108.4431 - 21.8313X + 1.0665X^2$	0.83^{xx}	xx
Los Angeles	$Y = 101.4719 - 14.2489X + 0.5462X^2$	0.93^{xx}	xx
Jiron 3-C	$Y = 97.9471 - 3.7760X - 0.08699X^2$	0.79^{xx}	xx

xx — Significant at 1% level

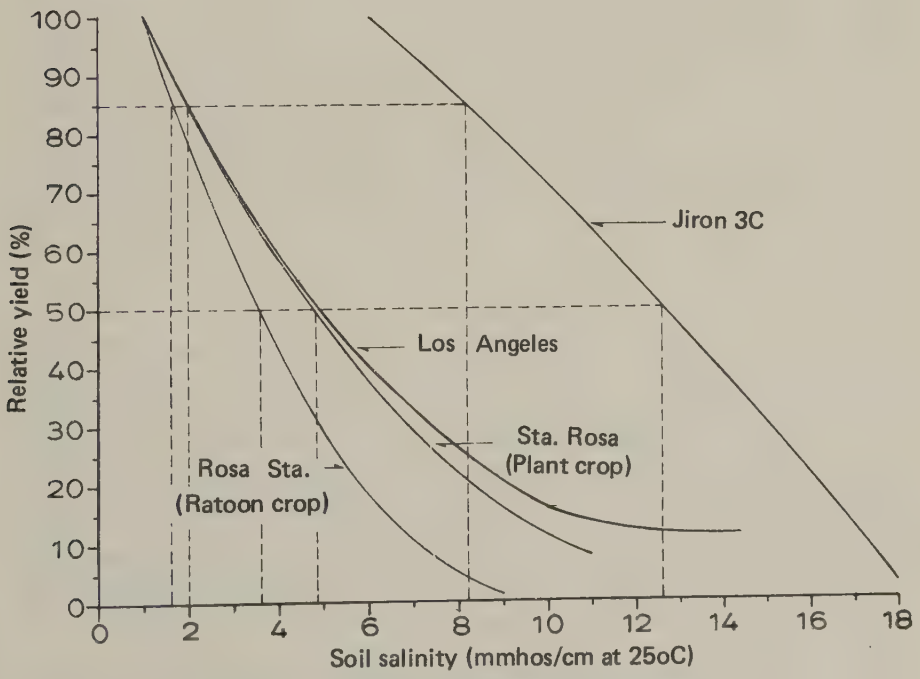

FIGURE 1. Soil salinity effect on sugarcane relative yield.

Rosa and Los Angeles fields practically behaved similarly with 2 mmhos/cm, the critical level in both cases. In these fields, 4.9 mmhos/cm decreased yield by 50%. Considering only these 3 experiments, the critical level varies between 1.6-2.0 mmhos/cm, indicating that sugarcane is sensitive to salts, according to FAO/UNESCO[5]. On the other hand, Jiron 3-C field behaved differently. 8.2 mmhos/cm is the critical level, and a salinity of 12.6 was required to reduce yield by 50%.

Yield Differences Between Plant and Ratoon Cane

Santa Rosa field was affected by relatively low salts concentration, the critical level being 2 mmhos/cm (15% of relative yield reduction) in plant cane and 1.6 mmhos/cm in ratoon. At low salinity level plant and ratoon yields were practically the same, but at high salinity level ratoon cane was strongly affected, yielding much less than plant cane. For an EC of 2 mmhos/cm ratoon yields 7% less and for a EC of 8 mmhos/cm, ratoon yields 77% less than plant cane. The less salts tolerance by ratoon cane has been reported by other workers (Robinson and Worker[20], Bernstein *et al*[2]).

Sodium Negative Effect

The low level of salt affected cane in Santa Rosa field because this field (saline-sodic) also had negative effect on the high exchangeable sodium percentage, which varies between 2 and 45 (Valdivia[27]). This agrees with Bonnet's[3] statement that sugarcane grows poorly in saline lands that contain from 20.0 to 72.9% of exchangeable sodium (pH 8.3 to 9.2) and EC (1:2 soil water suspension) from 1.5 to 3.7 mmhos/cm. Good sugarcane growth was observed when the saline land contained 4.5 to 11.4% of exchangeable sodium and EC from 0.3 to 0.6 mmhos/cm. Likewise, Fogliata and Aso[6], in Tucuman saline-sodic soils, recommended that the EC value should be under 1 mmhos/cm and the exchangeable sodium % under 12 in order to have an acceptable sugarcane yield.

Salinity Ground Water Depth Interaction

Los Angeles and Jiron 3-C fields have very similar climatic and chemical characteristics (Table 1), differing only in the finer texture of Los Angeles field. The principal difference between these two fields was that in Los Angeles, the water table level in general was under 2 m, while in Jiron 3-C the groundwater level fluctuated between 0.8 and 1.1 m. This relatively high water table allow normal cane growth even to salinities as high as 8.2 mmhos/cm. At this salinity level Los Angeles field yielded only 25% of the maximum. In studied valleys where water is scarce, cane is irrigated each 25 to 40 days, so that when the water table level is deep (Los Angeles) the salts damage effects (O.P.) are added to soil dryness conditions (high matric suction). This accounts for the relatively low critical level (2 mmhos/cm) in this field. The contrary occurs in Jiron 3-C field, where cane had a permanent water supply from groundwater. Hunsigi and Srivastava[10] indicated that a water table at depth of about 1 m contributed 65% towards the total Et of sugarcane and had no deleterious effect on growth, yield and quality of cane, and concluded that for optimum growth and yield the water table level should be kept below 1 m. This proves that there is a manifest interaction between salts damage effects and the water table depth as a source of water supplying to the plant. Therefore, it would be convenient to set critical salt concentrations levels for normal cane growth, taking into account the water table depth.

Groundwater must not be excessively shallow to avoid salt damage

because the required percent space for normal growth of sugarcane must be considered. Scarsbrook, (in Robinson[19]) found an adequate range to be 9 to 10%. Furthermore, Robinson[19] found that an average air space of 11% allowed the normal functioning of cane roots. On the other hand, Kamerling (in Van Dillewijn[29]), verified that sugarcane roots respiration continue intensively even when surrounding soil atmosphere contains little oxygen. Likewise, Risseeuw[18] indicated that sugarcane seems to support well excessive humidity conditions during a considerable time. It should also be necessary to take into account that O_2 deficiency causes reductions in root respiration, and a considerable amount of O_2 is required in the soil for mineralization of nutrient elements from organic matter by microbiological activity, although under the Peruvian soil conditions poor in organic matter, mineralization is of lesser importance. Visser (in Wesseling[31]) concluded that a water table depth of 50 to 60 cm below surface is sufficient to fulfill aeration requirements of plants. This would imply that the higher yields obtained at deeper water table can be completely ascribed to additional N becoming available under better aeration conditions. Wesseling[30] indicated that the normal root depth of arable crops in homogenous soils without root-restricting layers is somewhere between 90 and 120 cm. Taking the value of 90 cm the clay soil delivers about 190 mm of water if the drain depth is 100 cm. The sandy soil under the same conditions, however, will provide only about 125 mm of water. Therefore, although the depth of the ground water has no direct influence on crop growth, it indirectly determines the aeration conditions and the prevailing moisture conditions and therefore has an influence on water supply. This is of great importance in sugarcane areas of Peru where drought is frequently decreasing yields strongly, principally in saline soils with deep groundwater (more of 2 m). For this, Risseeuw[18] indicated that lower ground water level dose not always allow more profits. However, under the present conditions where normally ground waters are salines, shallow water tables (less of 1 m) can produce progressive salt accumulation which would damage sugarcane, even though most of the water is absorbed from the zone of low tensions near the water table.

An attempt to integrate above-mentioned factors was made by Valdivia and Pinna[28] who related the total soil suction effect (matric suction + osmotic suction) with the air space %, concluding that 3.5 and 2.2 mmhos/cm, at depths of 0-30 and 30-60 cm respectively, were the theoretical salt effect limit for sugarcane.

CONCLUSIONS

Under irrigation conditions in extremely arids zones and with sugarcane cultivar H32-8560, there was a highly significant correlation between relative cane yield and soil salinity for the four experiments evaluated. To obtain a good sugarcane production in saline and saline-sodic soils, the salinity in the 0-60 cm layer must not be higher than 2.0 mmhos/cm. In saline fields with shallow ground water table (80-110 cm), sugarcane was a salt semi-tolerant crop while in saline fields with deep groundwater table (below 2 m), sugarcane was a salt sensitive crop. In saline fields with shallow groundwater table (80-110 cm) it is possible to obtain good yields even with salinities as high

as 8 mmhos/cm.

In saline-sodic fields it was found that at high salinity, ratoon cane is more affected than plant cane. Furthermore, in said soils aside from the damage effect of salts, damage effect of sodium is added for which the critical level of salinity is low (1.6-2.0 mmhos/cm).

The large distance between irrigations in saline soils with deep ground water (below 2 m) raises salts damage effects, and lowers the salt critical level (2 mmhos/cm). Ground water tables between 80 to 110 cm depth, supplied sugarcane with water. In saline soils, the damage effect of salts is in terms of the groundwater table depth.

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EFECTO DE LA PROFUNDIDAD DE LA NAPA FREATICA EN EL NIVEL CRITICO DE SALES PARA LA CAÑA DE AZUCAR

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RESUMEN

Actualmente se dispone de gran cantidad de trabajos que relacionan la producción de la caña de azúcar con la concentración de sales del suelo, pero los niveles críticos son a veces diferentes. Por otra parte muchos artículos sobre la profundidad optima de la napa freática, han sido publicados, pero el problema, usualmente ha sido tratado como una relación suelo-agua sin tener en consideración la salinidad.

En el presente trabajo se discuten los efectos dañinos de la salinidad en funcion de la profundidad del nivel freatico, encontrandose que en campos salinos con napa freática superficial (80 a 110 cm)

se pueden obtener buenos rendimientos aún con salinidad tan alta como 8 mmhos/cm. En cambio, en campos salinos con napa freatica profunda (por debajo de 2m) soló bastan 2 mmhos/cm para bajar el rendimiento en un 15%. Este efecto tan dañino se explica si se tiene en cuenta que bajo condiciones del estudio (Perú) la caña se riega cada 25 a 40 diás. También se encontró que en suelos salino-sódicos, además del efecto perjudicial de las sales se suma el efecto dañino del sodio, todo lo cual hace que el nivel crítico de afectación por sales sea bajo (1.6 a 2.0 mmhos/cm.).

SUGARCANE RESPONSE TO FILTER APPLICATION ON TRINIDAD SOILS

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ABSTRACT

The average composition of filter mud (FM) produced in five Trinidad factories was found to be similar to that reported from other countries. The effects of FM broadcast at 125 ton/ha on cane and sugar yields in plant cane and subsequent ratoons were observed for a variety of Trinidad sugarcane soils. Significant cane yield increases were observed in five of six trials and average 37% in plant cane. In subsequent ratoons a steadily decreasing response was observed. It remained significant in two trials up to the second ratoon. Cane quality was not reduced. Soil and leaf phosphorus (p) levels were increased by FM treatments and remained higher than controls in some cases for at least three years. Other nutrients were less affected.

The availability of P in FM and triple superphosphate (TSP) was compared on two soils. At equivalent rates of P, no important differences were found. On a P-deficient sandly loam soil, 25 ton/ha banded in the cane row was as effective as 125 ton/ha broadcast and increased cane and sugar yields significantly over the equivalent rate of TSP.

INTRODUCTION

Filter mud (FM) is a by product of the clarification of cane juice, containing considerable quantities of nutrients (Samuels and Landrau[15], Prasad[12]). Its use as a fertilizer and soil ameliorant has been reported from several countries including Guyana (Paul[11]), Jamaica (Eastwood[6]), Hawaii (Hagihara[9]), Louisiana, USA (Golden[8]) and South Africa (Alexander[3]). However, some studies with FM have shown cane yield decreases (Samuels and Landrau[15]) and poorer cane quality (Golden[8], Moberly and Meyer[10]).

In Trinidad, Prasad[13] reported some dramatic increases in cane yield and improved cane quality on some soils low in P. He attributed part of these effects to factors other than the P component of FM. However, the nutrients, especially P, were much higher than the rates applied in inorganic fertilizers.

Eastwood[7] concluded that FM provided no beneficial effect other than its phosphorus under Jamaican conditions. The residual effect of FM over several crop cycles was not reported by Prasad[13] except at one location in 1st ratoon.

This paper reports the residual effects of those trials initiated by Prasad[13] and others on a wider range of soils. Also reported are results of some trials with FM application at lower rates supplying P equal to that supplied by normal commercial rates of TSP application so that FM and triple superphosphate (TSP) as sources of P under Trinidad conditions could be compared.

MATERIALS AND METHODS

The experiments were conducted on a range of soil types used for sugarcane cultivation in Trinidad. Some characteristics of these soils are given in Table 1. They have been described in detail by Brown and Bally[4]. Details of the trials are given in Table 2. Trials 1, 2, 4 and 5 were started in 1972 and 1973. Details of these trials, and the results obtained in plant cane were reported by Prasad[13]. The FM plots formed the main plots in a split plot design with fertilizer treatments as sub-plots in a study of FM-fertilizer interactions. The trials were continued to study residual effects of FM in ratoon cane. Fresh filter mud was uniformly broadcast over the soil by muck spreader and ploughed in Trials 1 to 6. The composition of FM produced in Trinidad is given in Table 3. In the sample plots trials (Trials 7-9) the FM was applied by hand, either broadcast, or in the row and covered lightly with soil. All applications were made several weeks before planting. Fertilizers were applied by hand, either in the planting furrow shortly before planting, or on the cane row within four weeks of ratooning. Sources of N, P and K were ammonium sulphate, triple superphosphate (TSP) and potassium chloride respectively.

Cane was cut by hand and weighed either by sling and bipod or by a tractor mounted hydraulic load cell. In the large plot trials (Nos. 3 and 6), cane weights were obtained from a crane mounted load cell after hauling the bundles from the field.

Ten to twenty representative stalks from each plot were ground in a Jeffco cutter-grinder and cane quality was determined using the method of Tanimoto[16].

Soil samples were taken from 20 cm depth in the cane ridge and comprised 16-30 cores per plot. The following determinations were made on the air dried 2 mm fraction: pH (Soil-water ratio of 1:2); P (extraction 0.002N H_2SO_4) by phosphomolybdic acid; K, Ca and Mg (extractant in NH_4OA_C) by flame photometer and atomic absorption spectrophotometer.

Lead samples, comprising the center 20 cm section of at least 16 TVD laminae with mid ribs removed, were taken from each plot. The samples were dried at 80°C for 48 hours to determine moisture percentage and then ground for analysis to pass a 1 mm screen. After digestion with H_2SO_4 and H_2O_2,

TABLE 1. Characteristics of the Soils Used in the Field Experiments

Trial No.	Location	Soil		Particle size Distribution			Chemical composition				
		Type	Classification	Clay	Silt	Sand	pH	P	K	Ca	Mg
					%				ppm		
1	Felicite	Fredirick clay	Mollisol	76	24	0	5.2	5	130	1566	415
2	Petit Morne	Talporo clay	Vertisol	77	14	9	4.9	16	164	.....	.....
3	Picton	La Fortunee clay	Vertisol	69	16	15	5.4	16	188	5100	1360
4	Waterloo	Waterloo clay	Alfisol	48	24	28	4.8	3	74	.....	.....
5	Devenish	Freeport clay	Alfisol	44	24	32	4.7	9	90	312	88
6	Waterloo	Waterloo clay	Alfisol	68	28	4	4.8	21	185	2165	392
7	McBean	Mc Bean S. loam	Ultisol	19	4	77	4.0	5	61	136	31
8	McBean	Mc Bean S. loam	Ultisol	16	27	57	4.7	3	86	.....	.....
9	Exchange	Waterloo clay	Alfisol	43	24	33	4.5	2	128	.....	.....

N, P and K were determined as follows:

N — by Nesslerization and spectrophotometry at 408 mu
P — by phosphomolybdic acid using ascorbic acid as reductant
K — by flame photometer

RESULTS AND DISCUSSION

Filter mud composition

The composition of Trinidad filter mud presented in Table 3 was similar to data previously reported for Trinidad (Prasad[12]). The most notable difference was a higher P value more similar to those reported from other countries (Alexander[2], Samuels and Landrau[15], Eastwood[6]). Troug's reagent (0.002N H_2SO_4) extracted 86% of the total phosphorus. A similar value for available P was reported for South Africa (Alexander[2]). Wet sieving of fresh FM showed that approximately 30% of the FM (dry weight basis) was composed of particles, mostly cane fibers, larger than 0.2 mm.

Cane grown and sugar yield

Data for the field trials where FM was broadcast and ploughed in at 125 t/ha are presented in Table 4. There were significant increases in plant cane yield in five of the six trials. Trial 6, on a heavy Waterloo clay well supplied with P did not show a significant increase. The mean increase in cane yield for all six trials was 37%. The largest increases were obtained on the lighter clays at Waterloo and Devenish (Trials 4 and 5) where initial soil P levels were low.

In 1st ratoons, the residual effect of the FM applied before planting was reduced in all trials and was significant in only three of five trials. Trial 3 was terminated due to the incidence of sugarcane smut disease *(Ustilago scitaminea)*. Mean increase from FM was 12%. Trials 4 and 5 were continued to 2nd ratoon where significant cane yield increases of 12% due to FM were observed.

Other workers have reported variable residual effects of FM in subsequent ratoon crops, Brown[5] and Eastwood[7] reported no residual effect of FM on cane yields, while Golden[8], observed significant residual effects. In S. Africa, residual effects are dependent on the soil used (Moberly and Meyer[10]).

There was a significant improvement in cane quality due to FM in Trial 4 only, for both plant canes and 1st ratoons (Table 5). In the other trials there were no significant effects on cane quality and sugar yields followed the trends observed in cane yield. This is in contrast with several reports in other countries where Fm application reduced cane quality (Moberly and Meyer[10], Golden[8], Samuels and Landrau[15]).

TABLE 2. Details of Field Trials

Trial No.	Location	Date planted	Soil type	Variety	No. of times reaped	Plot size m^2	Rate tons/ha (fresh wt)	FM application Model(1)	Fertilization N	P	K
									kg/ha		
1	Felicite(2) (3)	July 1973	Frederick clay	HJ 5741	2	356	0.125	B.P	47.94 & 141	0.45	0.112
2	Petit Morne(2)	Sept 1973	Talparo clay	HJ 5741	2	535	0.125	B.P	47.94 & 141	0.45	0.112
3	Picton(4)	Aug 1975	La Fortune clay	HJ 5741	1	1012	0.125	B.P	105	49	130
4	Waterloo(2)	June 1972	Waterloo clay	HJ 5741	3	356	0.150	B.P	0.94 & 188	0.45 & 90	224
5	Devenish(2)	July 1973	Freeport clay	HJ 5741	3	535	0.125	B.P	47.94 & 141	0.45	0.112
6	Waterloo(4)	Aug 1976	Waterloo clay	B 41227	2	810	0.125	B.P	105	49	130
7	Mc Bean (4)	July 1976	Mc Bean sandy loam	B 41227	2	101	0.125	Bd	158	49	130
8	Mc Bean	July 1978	Mc Bean sandy loam	B 41227	1	41	0.25 50.125	Bd & B	158	0.61	130
9	Exchange	July 1978	Waterloo clay	B 41227	1	101	0.25 50.125	Bd & B	158	0.61	130

(1) *B = broadcast application; Bd = banded under cane row; P = ploughed in.*
(2) *FM treatments formed main plots in FM x fertilizer interaction, details of which have been reported previously Prasad 13*
(3) *All trials were randomized complete blocks with 4 replications, except trials 3 and 4*
(4) *Trial included other rates of FM and other amendments not reported here.*

The results obtained in plant cane in trials 8 and 9 where the effects on FM applied at 25, 50 and 125 t/ha were measured, are shown in Table 6. It can be seen that 50 t FM (broadcast) was as effective as 125 t FM in both trials and 25 t FM applied in the row was as effective as the broadcast applications. In trial 8 phosphorus deficiency symptoms were observed in the young cane growing in control plots and TSP application, supplying 61 kg P/ha, increased cane yield by 44% over the no-P control. However, 25 t FM containing the same amount of P significantly outyielded the TSP treatment by a further 27%. On the alfisol (Trial 9), which is also tested low for soil P, there was less response to TSP applications (17%) and to FM. Filter mud, broadcast at 50 and 125 t/ha significantly out–yielded the TSP. In trial 7, on a very similar site to trial 8, 25 t FM increased cane yields by 19% in plant cane and by 10% in 1st ratoons over the TSP treatment.

Cane quality was not significantly affected in either trial, and sugar yields generally followed the trends in cane yield.

Phosphorus

In trials 1-6, where FM was applied at 125 t/ha, soil-P levels were raised considerably above those in control plots. Increases at 6 months ranged from 57-250% (Av. 131%) and were maintained in some cases over three years. These dramatic increases are not surprising considering that 125 t FM supplies approximately 300 kg P and they have been reported previously in Trinidad (Prasad[14]) and elsewhere (Golden[8]). Leaf P levels were increased by FM in plant cane in five of the six trials, and were maintained in 1st ratoon in three out of four trials observed.

Where comparable levels of P were applied as TSP of FM (trials 8 and 9), little difference in available soil – P was observed except at 3 months, where TSP gave higher levels in both soils (Table 7). This is in agreement with incubation studies on four Trinidad soils where at 3 months, TSP maintained a higher extractable-P level than FM containing equivalent amounts of phosphorus (Abu-Idris[1]). Leaf-P levels in these two trials however, did not indicate any difference in P supply from the two sources. In Jamaica, Eastwood[7] found TSP and FM at equivalent rates supplied P equally well.

Other nutrients

Effects on other nutrients were similar to those reported previously (prasad[14], Golden[8]). Leaf-N was higher in FM treatments in four of the nine trials but these differences generally did not carry through to 1st ratoon.

There were also small increases observed in soil-K (7%), soil-Ca (22%) and soil Mg (18%). These effects were frequently accompanied by slight increase in leaf nutrient levels in plant cane, but were negligible in subsequent ratoons. Effects were generally more pronounced on lighter textured soils.

TABLE 3. Composition of Fresh Filter Mud Collected from Trinidad Sugar Factories[1]

	Particle analysis[2]			Macronutrients[3]					Micronutrients[3]					
Moisture content %	Coarse fiber % Dry Weight	Fine fiber	Non-fibrous	N	P	K	Ca	Mg	Fe	Mn	B	Cu	Zn	Mo[4]
				% Dry Weight					ppm Dry Weight					
73	6.6	21.0	72.4	1.33	1.01	0.47	2.09	0.26	3500	1800	6	50	350	15

(1) *Average of 6 sampling from 5 factories taken during early, middle and late periods of harvesting season.*

(2) *Coarse fibers – retained on 0.85 mm sieve; Fine fibers – retained on 0.25 mm sieve; Non-fibrous – material passing 0.25 mm sieve.*

(3) *Micronutrients analyzed by emission spectrograph, macronutrients analyzed as leaf material.*

(4) *Data taken from Prasad*[12].

TABLE 4. The effects of Filter Mud at 125 tons/ha of Successive Crops of Sugar Cane on Cane Yield

Crop History	1 Felicite			2 Petit Morne		
	Control	FM	Difference	Control	FM	Difference
	Tons/ha		%	Tons/ha		%
Plant cane	77.0	94.3	23	103.4(2)	128.0(2)	24(2)
1st Ratoon	91.3	94.1	3(3)	90.6	97.1	7
2nd Ratoon	....	....	...	.....	.....	...
Total	168.3	188.4	12	194	225.1	16
	3 Picton			4 Waterloo		
Plant cane	76.3	99.6	31	58.7	94.5	61
1st Ratoon	....	....	...	96.3	126.5	31
2nd Ratoon	....	....	...	90.6	101.1	12
Total	....	....	...	245.6	321.9	31
	5 Devenish			6 Waterloo		
Plant cane	64.5	112.7	75	73.0(2)	78.3(2)	7(3)
1st Ratoon	126.2	149.3	18	56.7	58.0	2(3)
2nd Ratoon	71.0	79.5	12	....	....	...
Total	261.7	341.5	31	129.7	136.3	5(3)

(1) *FM applied at 150 tons/ha.*
(2) *Standover plants (18 months old)*
(3) *Difference not significant (P = 0.05), all other differences significant (P = 0.05)*

TABLE 5. The effects of Filter Mud at 125 Tons/ha of Successive Crops of Sugar Caneon Sugar Yield.

Crop History	1 Felicite			2 Petit Morne		
	Control	FM	Difference	Control	FM	Difference
	Tons/ha		%	Tons/ha		%
Plant Cane	10.2	12.6	23	12.8	15.6	21
1st Ratoon	11.3	11.7	3	11.4	12.2	8(2)
2nd Ratoon	....	....	..	....	....	..
Total	21.6	24.2	13	24.2	27.8	15
	3 Picton			4 Waterloo FM(1)		
Plant cane	10.3	13.2	28	7.1	12.4	76
1st Ratoon	....	....	..	11.5	15.8	37
2nd Ratoon	....	....	..	10.8	12.3	14
Total	....	....	..	29.4	40.5	38
	5 Devenish					
Plant cane	7.6	14.3	90			
1st Ratoon	18.8	22.2	18			
2nd Ratoon	8.8	9.8	12			
Total	35.1	46.3	32			

(1) FM applied at 150 Tons/ha

(2) Difference not significant (P = 0.05), all other differences were significant (P = 0.05).

TABLE 6. Effects of Phosphate Fertilizer and Filter Mud Applied at Different Rates and in Different Ways on Plant Cane and Sugar Yields[1]

Treatments[2]	McBean (8)[3]			Exchange (9)		
	Cane yield tons/ha	Cane quality Sugar % cane	Sugar yield tons/ha	Cane yield tons/ha	Cane quality Sugar % cane	Sugar yield tons/ha
P0	66.9 a[4]	13.8 a	9.26 a	63.7 a	15.1 a	9.66 a
P1	96.3 b	14.4 a	13.84 b	74.4 b	15.2 a	11.61 b
F1 R	114.5 c	15.0 a	17.19 c	75.2 bc	15.4 a	11.67 b
F2 R	117.7 c	14.0 a	16.52 bc	74.7 b	15.2 a	11.23 b
F2 B	115.5 c	13.9 a	16.07 bc	80.6 c	15.5 a	12.24 b
F5 B	116.3 c	14.8 ba	17.19 c	80.6 c	15.6 a	12.42 b
CV (%)	10.0	4.4	11.6	4.7	3.8	6.5

1 *Plant cane harvested at 9 months*

2 *Phosphorus applied as Triple Superphosphate at rates of either 0 (PO) or 61 kg p/ha (PI) in the cane row. Filter mud applied before planting either in cane row (R) or broadcast (B) rates of 25 (F1), 50 (F2) or 125 (F5) tons/ha (fresh weight).*

3 *Numbers in brackets denote Trial number.*

4 *Values in same column with same letter not significantly different (P = 0.05) using Duncan's Multiple Range Test.*

TABLE 7. The effects of TSP and Filter Mud on available Soil Phosphorus Levels in Two Soils

Treatment[3]	McBean sandy loam (8)[2] Time sampled[4]			Waterloo clay (9) Time sampled[4]		
	3	4.5	6	3	4.5	6
	ppm					
P0	6	11	2	4	2	4
P1	34	24	9	21	7	15
F1 R	14	19	9	10	6	7
F2RR	29	23	12	19	8	33
F2 B	27	25	12	13	3	11
F5 B	45	22	17	19	2	41

(1) *0.002N H_2SO_4 pH3, used as extractant*
(2) *Numbers in brackets denote trial number*
(3) *See Table 6, Note 2*
(4) *Months from planting. FM applied 2-3 weeks previously*

TABLE 8. The effects of TSP and Filter Mud on Leaf-P Levels in Two Soils

Treatment[2]	McBean sandy loam (8)[1] Time sampled[3]			Waterloo clay (9) Time sampled[3]		
	3	4.5	6	3	4.5	6
	% dry wt					
P0	0.178 a[4]	0.178 a	0.187	0.231 a	0.226 a	0.204 a
P1	0.252 b	0.225 b	0.208	0.277 b	0.243 b	0.218 a
F1 R	0.259 bc	0.222 b	0.206	0.273 b	0.241 a	0.208 a
F2 R	0.289 cd	0.226 b	0.206	0.304 b	0.251 b	0.214 a
F2 B	0.274 bcd	0.228 b	0.197	0.286 b	0.252 b	0.212 a
F5 B	0.304 d	0.234 b	0.210	0.327 c	0.252	0.221 a

(1) *Number in brackets denote trial number*
(2) *See Table 6, note 2*
(3) *Months from planting*
(4) *Values in same column with same letter are not significantly different (P = 0.05) using Duncan's Multiple Range Test.*

CONCLUSION

From the results of these trials it can be concluded that FM as produced in Trinidad is similar in composition to that in other countries and that most of the phosphorus was readily available to sugarcane. At 125 t/ha, FM was able to raise soil-P levels substantially over a period of several years and supply smaller amounts of other nutrients. However it was not more efficient than TSP in supplying P when used at equivalent rates of phosphorus.

Filter mud was effective in increasing cane and sugar yield over more than one crop on a variety of Trinidad soils, smaller responses being obtained on the heavy clays. In plant cane, 25 t applied in the row before planting was as effective on two soils as 125 t/ha broadcast.

Only part of the cane yield response to FM was due to its P content in the eighteen texture soils.

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RESPUESTA DE CAÑA DE AZUCAR A APLICACIONES DE CACHAZA EN SUELOS DE TRINIDAD

Brian R. Cooper y E. A. Abu Idris

RESUMEN

La composición promedio de cachaza (FM) producida en cinco factorías en Trinidad se encontró similar a lo reportado desde otros países. Se observaron los efectos de aplicar cachaza al voleo a 125 t/ha en relacion a los rendimientos de caña y azúcar en plantilla y subsiguientes retoños en varios suelos de Trinidad. Se observaron aumentos significativos en rendimiento de caña en cinco de seis ensayos, promediando 37% en plantilla. En los subsiguientes retoños se observaron respuestas que decrecían progresivamente. Se mantuvo significativa en dos ensayos hasta el segundo retoño. La calidad de la caña no fue reducida. Los niveles de fósfóro en el suelo y las hojas aumentaron con los tratamientos de cachaza y se mantuvieron más altos que los controles en algunos casos hasta por lo menos tres años. Otros nutrientes fueron menos afectados.

La disponibilidad de P en cachaza y triple superfosfato (TSF) se comparo en dos suelos. A dosis equivalentes de P no se encontraron diferencias importantes. En un suelo deficiente en P de textura franco arenosa fúe tan efectivo aplicar 25 t/ha de cachaza en bandas en la hilera de caña como 125 t/ha al voleo y aumentó los rendimientos de caña y azucar significativamente sobre la dosis equivalente de TSF.

EFFECT OF LIMING ON THE PRODUCTION OF SUGARCANE AND ON THE FERTILITY OF THE SOIL IN THE STATE OF PERNAMBUCO

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ABSTRACT

An experiment using red-yellow latosol soil from the Southern Pernambuco sugarcane plantation zone was conducted in pots, to find out the effects on the dry sugarcane matter and soil fertility from the liming levels corresponding to 3.56 (Al = 0 meq); 1.40 (Al = 0.5 meq); 1.04 (Al = 1.0 meq) and 0.64 (Al = 1.5 meq) t/ha of $Ca(OH)_2$.

The effect of liming on the dry matter production of the aerial part of the sugarcane was confirmed. In the roots, in spite of the decrease of the liming level, no significant statistic was detected.

The different levels of $Ca(OH)_2$ decidedly influence the absorption of Ca and Mg by the aerial part of the cane. The liming increase caused the elevation of the Ca and Mg contents and the saturation of the bases and reduced the Al and H contents of the soil. With the exception of P, the extreme values were obtained with 3.56 t/ha of $Ca(OH)_2$.

The correlations between t/ha of $Ca(OH)_2$ vs $(Ca^{+2} + Mg^{+2})$ meq and t/ha of $Ca(OH)_2$ vs Al^{+3} meq on the soil were significant at the coefficients for $(Ca^{+2} + Mg^{+2})$ meq and negative for Al^{+3} meq, though both were equal in absolute value.

INTRODUCTION

The sugarcane cultivation in the State of Pernambuco is restricted to two distinct zones: Northern zone and Southern zone. The two zones have sufficiently distinct soil characteristics, topography and climatic conditions. The Southern zone, being the most traditional area for Graminae cultivation,

presents a very irregular topography, high rainfall and most of its soil falls into the classification of having horizon B latosol (not hydromorphic), where by means of the process of lateritization, the convertible bases and the silica that are not removed from the arable layer by washing (Ayres[1]), remain as the acid forming agents.

This becomes more evident when the analytical parameters revealed by the soil analysis are known and where they reveal average and high contents of Al^{+3} and low contents of Ca^{+3} and Mg^{+2} as compared with standards for other crop regions. As described, it would be normal that, specifically in this region of sugarcane cultivation, the practice of liming had been a sufficiently representative function in the Graminae cultivation activities.

Inspite of so many evidences, the use of limestone, either to correct acidity or to supply Ca and Mg in the soil, has not yet been rationalized due to a few factors, such as the use of limestone without prior knowledge of its physical and chemical characteristics; the lack of effective methods of incorporation and principally the inexistence of conclusive information about the practice. On the other hand, some producers have used lime of the land for enough time and argue that the practice has increased the number of second harvests of the cane-breaks.

In this light, the importance of liming in these soils can be really justified by the chemical characteristics, by the need to increase the productivity, as well as by the scarcity of fertilizers produced in the region. These assumptions are reinforced by the statement of Kamprath[7] that soils of humid regions are generally acid in all aspects and that little advantage is obtained from the fertilizers due to the lack of liming, resulting in the low production of the plants.

Laroche[8], after consulting various authors, defines liming as a technique of incorporating calcium and magnesium carbonates hydroxides and oxides into the soil in order to increase the supply of calcium and magnesium going to the plant thus correcting the noxious effect of the high acidity.

Kamprath[7] states that for acid mineral soils, quantities of limestone based on the content of exchangeable Al multiplied by a factor of between 1.5 and 2, would eliminate the principal agent and would promote the elevation of productivity

For sugarcane, the liming has been a polemic subject all over the world. The results obtained by experimentation with limestone lead to results that to a certain point, are constricting. In certain localities, benefits are obtained with the practice (Ayres[1]) while in others, liming does not modify the yielding (Ayres[1] and Cordeiro[4]). However, information exists that gives sufficient emphasis to limestone as a supplier of calcium and magnesium to the soil; of course, sugarcane would be a little sensitive to the normal contents of exchangeable Al.

One thing that remains perfectly settled is the need to develop wise

programs to define parameters for the use of limestone. Laroche[8], states that in the tropical countries, the agricultural is superior to industrial production and that 40% or more of their population dedicate themselves to agriculture. Therefore, the adequate use of limestone could become an economic factor, in terms of increasing the potentialities of the soils.

The objective of this present work was to determine the effect of liming on the elimination of exchangeable aluminum, as well as to determine its effect in the production of dry matter in sugarcane.

MATERIALS AND METHODS

A red yellow latosol soil, described by Jacomine *et al*[6], from the Barreiros Central Sugar Mill-PE was used for the study of the effect of hydrated lime on the production of dry matter in sugarcane and in the constituents of fertility. Approximately 30 kg. of the upper 20 cm. of topsoil, corresponding to the arable layer, was collected and was packed in plastic vessels with holes in the bottoms for drainage. A mixed sample of soil from the 16 pots was collected and P, K, Ca + Mg, Al and pH were determined according to the methodology described by Vettori[11]. The results obtained are shown in Table 1.

TABLE 1. Original chemical analysis of the soil

P	K	Ca+Mg	Al	CEC
ppm	meq/100 ml			
3	0.06	0.10	2.40	2.56

The initial phase of the experiment consisted of laboratory work, where by means of the titration curve the necessary amounts of Ca $(OH)_2$ were determined for which the 0, 0.5, 1.0 and 1.5 mE levels of Al^{+3} in the soil were obtained and which will be considered as the theoretical treatments in the test. The extraction was made with 1N KCl in the proportion of 1:10 (10 ml. of soil:100 ml. of extractor solution). With the quantities determined to control the levels of exchangeable aluminum (Fig. 1), the hydrated lime was homogenized with the 20 cm. of top of each pot, water was added to approximately the field capacity and then they were left to incubate for 30 days.

The CB 45-3 variety was used for the test as it is the type planted most in the region. The shoots with the nodes were treated thermically in a thermal unit at 52°C for 30 minutes, after which the shoots were put in plastic boxes containing washed and sterilized sand to germinate. After 20 days of rooting, 5 plants with their respective nodes were transplanted to each pot. On this occasion, each pot was fertilized with the corresponding value of 30-150-60 kg/ha, respectively of N, P_2O_5 and K_2O, along with 5 kg/ha of Cu, Zn and B. Two fertilizations with 11 and 30 kg/ha respectively, of N and P_2O_5 were made after 30 and 60 days in order to correct the deficiencies of nitrogen

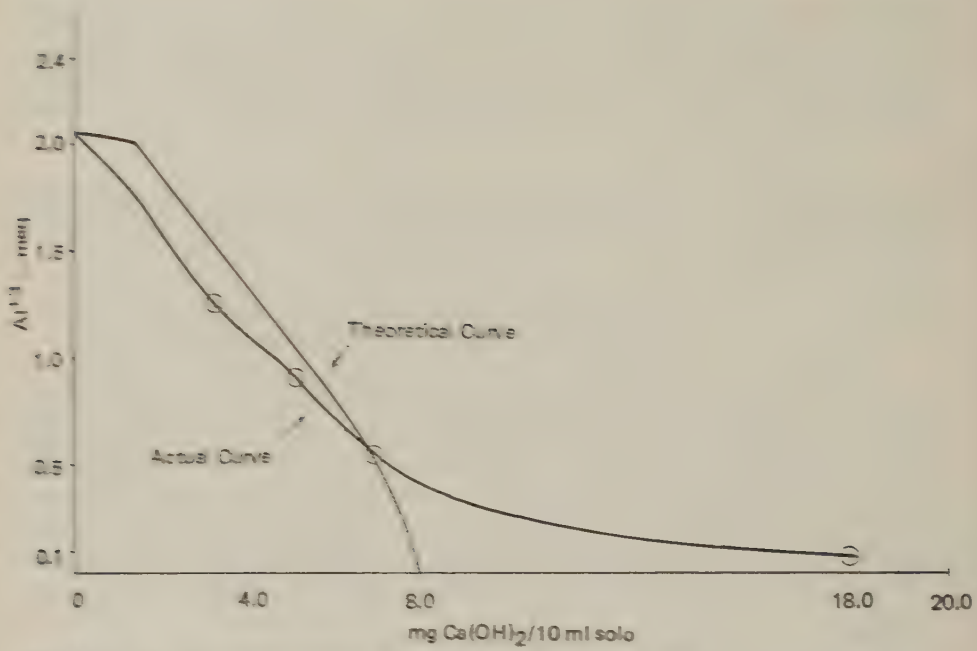

FIGURE 1. Titration curves of Exchangeable Aluminum.

and phosphorus. This last time, Mg was added to correct the nutrient deficiency, in the proportion of 1:6 (Mg:Ca) of the original content of the soil.

The pots were placed in random blocks, with the 4 treatments repeated 4 times, (Tables 2 and 3) in open sunlight at the PLANALSUCAR Sugarcane Experimental Station in Carpina. After 15 days, the two least developed plants were discarded from each plot, leaving three plants until the end of the tests. Irrigation when necessary, was done manually.

When the plants were 5 months old, they were harvested, separated into the aerial parts and roots, washed and placed in a continuous air circulation oven at 70-75°C to dry until they reached a constant weight. After this, the material was weighed and then ground in a Willey Nr. 20 screen grinder. At the time of harvest, the upper 20 cm of the topsoil from each pot was sampled and the phosphorus and potassium were extracted by the 0.05 N HCl + 0.025 N H_2SO_4 solution, the magnesium and aluminum were extracted with 1N KCl solution, and in both cases the proportion of the soil volume: solution volume = 1:10 as described by Vettori[11]. The determination of H^+ was done according to Catani and Jacinto[2]. The calcium and the magnesium of the aerial part and roots were determined by the methodology described in Sarruge and Hagg[10].

RESULTS AND DISCUSSION

Effect on the Dry Matter

The production of the dry matter (aerial part and roots), as well as

the percentage and total contents of Ca and Mg are shown in Table 2. It is shown that the liming caused modifications of the Ca and Mg absorbed (totals) were more accentuated than the percentage of concentrations of the same nutrients. In the first case, the statistical significance was in the 1% probability level. There was no statistical differences shown for the roots.

If we take the exchangeable Al as the indicator of the seed of liming, it is shown that the dosages used were arrived at by multiplying the contents found in the original condition of the soil by 1.05, 0.60, 0.40 and 0.30. This results approaches the information given by Kamprath[7], in that the multiplying factor would be between 1.5 and 2.5 noting that the maximum production of dry material was obtained with the multiplication factor approximately equal to 1.50.

Considering that the production of dry matter corresponds to 3.50 t/ha of Ca $(OH)_2$ (Al^{+3} x 1.50) for a good production, it can be observed that the percentage relation between Ca/Mg was approximately 2.8 for the aerial part and 3.8 for the roots. This reinforces the existing knowledge that the Mg is present more in photosynthesizing organs and the Ca in the growth tissues of the radicular system.

With respect to the radicular system, even without statistical proof, there was a tendency for the weight of the roots to increase in the same ratio that the quantity of hydrated lime applied was decreased. The roots with 1.5 meq of Al^{+3} treatment were short, dark and had an inferior appearance

Effects of the Chemical Properties of the Soil

The liming caused sufficiently accentuated modifications in the chemical constituents of the soil. Shown in Table 3 are significant differences of 1% probability in the contents of Ca + Mg, Ca, Mg, Al, H and V; a 5% probability for P and no significance for K and CEC. The differences were most accentuated for the saturation of the bases with exchangeable aluminum (Al).

All the original characteristics of the exchange complex suffered accentuated modification under the action of the treatments. If it is considered that the CEC of the soil could be obtained by means of the sum of the exchangeable cations of Al, Ca and Mg dislodged by KCl, as Coleman *et al*[3] emphasize, this original value was 2.5 meq and the Al x 1.50 treatment corresponds to 4.30 mE, which represents almost a twofold increase. Therefore, for $C_a{}^{+2}$ + Mg^{+2} there was an increase of 42 times (4.20 meq to 0.10 meq). Similar results to those obtained here were cited by Laroche[7] and Kamprath[6] for Ca and Mg.

The saturation of exchangeable Al reduced from 93% to 2% by the same process. The original P content (3 ppm) was sufficiently elevated, perhaps due to the additional of phosphorized fertilizers (80 ppm) and association with the short period of cultivation (5 months), and not to the liberation

TABLE 2. Effect of the treatments in the production of dry matter and in the concentrations (%) and extractions (g) of calcium and magnesium in the aerial part and root of the sugar cane plant.

$Ca(OH)_2$		Aerial Part					Roots				
g/pot	t/ha	Dry Matter g/pot	Ca %	Ca g	Mg %	Mg g	Dry Matter g/pot	Ca %	Ca g	Mg %	Mg g
35.6	3.56	173.05	0.47	0.82	0.17	0.29	84.20	0.19	0.16	0.05	0.04
14.0	1.40	149.04	0.39	0.58	0.13	0.18	91.27	0.20	0.18	0.02	0.02
10.4	1.04	170.76	0.39	0.66	0.11	0.19	89.00	0.17	0.16	0.03	0.02
6.4	0.64	137.49	0.37	0.50	0.11	0.15	108.85	0.18	0.19	0.03	0.03
F		6.70*	5.92*	8.33*	4.95*	12.69**	1.34	1.00	1.11	1.33	0.67
LSD (5%)		26.25	0.06	0.19	0.004	0.07	36.62	0.04	0.06	0.03	0.03
CV (%)		8.43	9.05	14.68	18.98	16.99	19.87	11.82	17.20	52.26	57.67

TABLE 3. Effects of hydrated lime in the chemical characteristics of the soil after cutting the sugarcane plant.

$Ca(OH)_2$		P	K	Ca+Mg	Ca	Mg	Al	H	CEC	V
		ppm	meq/100 ml							%
g/pot	t/ha									
35.6	3.56	54	0.45	4.2	2.5	1.7	0.1	3.0	7.8	60
14.0	1.40	85	0.36	1.5	1.2	0.3	1.0	3.9	6.8	27
10.4	1.04	64	0.36	1.2	0.9	0.3	1.3	4.4	7.3	20
6.4	0.64	62	0.36	0.9	0.7	0.2	1.6	4.6	7.5	16
F		5.47*	1.70	68.17*	48.33**	30.76**	101.34**	15.66**	1.31	224.61**
LSD (5%)		22.47	0.16	0.71	0.44	0.48	0.19	0.71	1.36	5.27
CV (%)		17.03	17.33	19.04	18.05	40.44	12.78	9.28	9.48	8.62

of the P held by the Al, as Kamprath[7] stated. On the other hand, it can be noted that the lowest value of P was obtained in the treatment that received 3.56 t/ha (Al^{+3} x 1.50), and this value statistically differs from the treatments that received 1.40 cm 0.64 t/ha of hydrated lime.

The effect of liming on the levels of exchangeable K in the soil did not cause modification, inspite of known studies that give sufficient emphasis to the Ca/K antagonism. It can be argued that the small quantities of hydrated lime applied were not sufficient to cause this phenomenon.

Studies of Regression

The liming caused modification in most of the chemical characteristics of the soil in question. What really constitutes doubt is exactly the knowledge of the factor that causes reduction of the growth of the plant — if it is the lack of Ca and Mg or the excess of exchangeable Al. Various authors have already made statements in this respect. Lee[9] cultivated potatoes in a nutritive solution and said that 20 ppm of Al in the solution — approximately 3 meq — reduced the growth of the aerial part and of the roots of all the varieties. Evans and Kamprath[5], in their turn, made distinction between exchangeable Al and Al saturation. The same authors said that corn responds to liming in soils where the aluminum saturation was more than 70%, as well as that a soil only does not respond to liming when the exchangeable aluminum was around 0.40 meq/liter (Approximately 0.04 meq).

On the other hand, some researchers prefer to focalize the liming as the supplier of calcium and magnesium to the plants. Ayres[1] for example, states that for sugarcane, calcium could be considered a limiting factor of growth. Kamprath[7], in his turn, prefers to attribute the possibility of supplying Ca and Mg, precipitation of Al and Mn, and greater availability for Ca and Mo to liming. He also states that Al affects the assimilation and movement of Ca in the plants.

The regression studies were done with the facts, whose averages are shown in Table 3, precisely to try to identify the factor that best oriented liming. The regression of hydrated lime and Ca + Mg of the soil (Fig. 2) and of hydrated lime and Al^{+3} (Fig. 3) created significant correlation coefficients of 1% probability and were exactly equal to the respective observed values ($r = 0.97$ and $r = -0.97$).

The regression between hydrated lime and the saturation index in soil bases (Fig. 4) is created from the two previous regressions, and also gives significance to the 1% probability level ($r = 0.99$). By what is shown, it becomes difficult to separate the effects of exchangeable Al and Ca^{+2} + Mg^{+2} in the soil on the production, since the material used in the liming — calcium and magnesium carbonates, hydroxides and oxides — always create accentuated modification in the two factors studied.

Meanwhile, what seems perfectly logical is the different sensitivities of

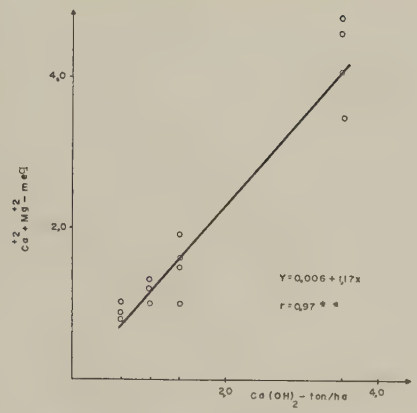

FIGURE 2. Relation between the added Ca (OH)2 and Ca ^{2} + Mg ^{2} of the soil.

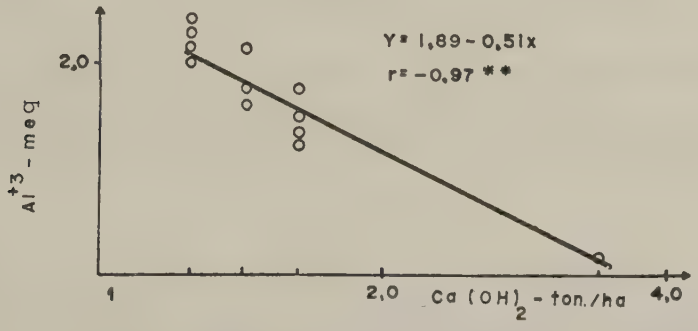

FIGURE 3. Relation between added Ca $(OH)_2$ and Al^{+3} of the soil.

certain plants to the exchangeable aluminum in the soil (Lee[9]). Richardson, as quoted in Laroche[8], states that some tropical plants such as rice and sugarcane, support the noxious effects of soil acidity well, and respond to the liming due to the supply of calcium.

CONCLUSIONS

Completing the discussions of all aspects raised, the following conclusions could be inferred.

- the aerial part of sugarcane experienced more significant increase with the liming than the radicular system did;
- the chemical composition of the soil suffered sensible variations in what is said in respect to the contents of Al^{+3}, Ca and Mg correlated better with the liming than with the production of dry material in the aerial parts;
- sugarcane showed itself sufficiently tolerant of the content of exchangeable Al in the soil. The treatment with Al^{+3} = 1.0 meq did not differ

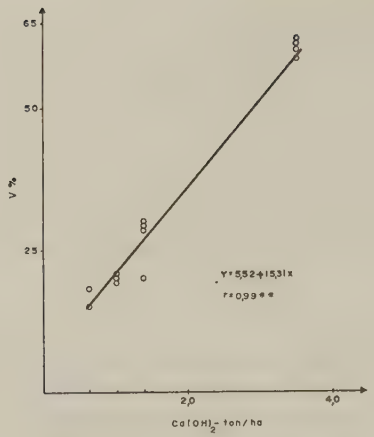

FIGURE 4. Relation between Ca $(OH)_2$ added and index of saturation of the bases (V%) of the soil.

from the treatment with $Al^{+3} = 0$ meq;

– the need of limestone (NC), could be obtained from the results of the product of the exchangeable Al in the soil times 1.5 (NC = meq Al^{+3} x 1.5).

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EFECTO DE ENCALAR EN LA PRODUCCIÓN DE CAÑA DE AZÚCAR Y EN LA FERTILIDAD DEL SUELO EN EL ESTADO DE PERNAMBUCO

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Antonio Pinto Medeiros y José Maria de A. Pereira

RESUMEN

Un experimento utilizando un suelo latosol rojo-amarillento de la zona cañera de Pernambuco Meridional se llevó a cabo en tiestos, con el objetivo de determinar los efectos en la materia seca de la caña de azucar y la fertilidad del suelo con niveles de encalamiento correspondientes a 3.56 (Al = 0 meq); 1.40 (Al = 0.5 meq); 1.04 (Al = 1.0 meq) y 0.64 (Al = 1.5 meq) t/ha de $Ca(OH)_2$.

Se confirmó el efecto de encalar sobre la producción de materia seca de las partes aéreas de la caña. No se detectó significancia estadistica en las raices a pesar de reducir el nivel de encalamiento.

Los diferentes niveles de $Ca(OH)_2$ decididamente influyeron en la absorcion de Ca y Mg en las partes aéreas de la caña.

El encalado aumento los contenidos de Ca y Mg y la saturación de los bases y redujo los contenidos de Al y H del suelo. Exceptuando al P. los valores extremos se obtuvieron con 3.56 t/ha de $Ca(OH)_2$.

Las correlaciones entre Al^{+3} en el suelo fueron significativas a 1% de probabilidad y presentaron coeficientes de correlacción lineales positivas para meq (CA^{+2} + Mg^{+2}) y negativas para meq Al^{+3}, sin embargo ambas fueron iguales en cuando a valor absoluto.

LIMING SOILS UNDER SUGARCANE IN MAURITIUS

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ABSTRACT

The variation of soil exchangeable Ca and Al with pH has been studied and used to explain the yield reponses of sugarcane to liming acid soils of Mauritius.

Liming did not improve the yield of sugarcane. This may be attributed to absences of Mn and Al toxicities and to the presence of a good Ca status in the soils. Soil investigations indeed showed that at pH greater than 5.0 exchangeable Al was reduced to negligible values while exchangeable Ca saturated more than 70% of the cation exchange sites and was not appreciably increased upon liming. Application of high doses of lime residue to soils may, on the contrary, depress the yield of sugarcane. The cause of this adverse effect of lime residue on sugarcane yield however remains unknown in Mauritius.

From the close association that exists among pH and soil exchangeable Ca and Al, liming acid soils under sugarcane in Mauritius should only become an indispensable practice when the soil pH falls below 5.0. Liming recommendations should therefore be aimed to raise the soil pH to 5.0 or 5.5.

INTRODUCTION

Liming is a common practice in the management of acid soils under sugarcane in Mauritius. The recommended liming rates are currently aimed at controlling soil pH *per se,* i.e. raising it to 6.0 or 6.5. Investigations of soil acidity correction have however shown that in the humid tropics, liming would be more effective and economical if it was aimed at eliminating exchangeable Al and at supplying Ca as a nutrient to the plant rather than at bringing soil pH to near neutrality (Reeve and Sumner[17], Pearson[16]). Exchangeable Al is in effect widely held to be the major cause of soil infertility in the tropics (Juo[9], Mendez and Kamprath[12]). Thus, Boyer[2] indicated that when Al occupies more than 45.50% of the cation exchange sites, crop yields would be below normal. On the other hand Al toxicity would not occur even for the most sensitive crop if Al saturates less than 5 to 10% of the exchange complex.

The need to lime an acid soil in fact depends upon the crop to be grown and

in this context sugarcane, very frequently, does not respond to lime applications (Paris[15], Pearson[16]). To provide a rational explanation to such apparent insensitivity of sugarcane to liming, the variation of exchangeable Al and Ca with pH in soils was investigated in the present study and discussed in relation to observed lack of yield responses of sugarcane to liming in Mauritius. The information gained is expected to provide a basis for the elaboration of judicious lime recommendations in Mauritius.

EXPERIMENTAL PROCEDURE

Exchangeable Calcium and Aluminum in Soils

Buffer curves for 15 soils representative of the Latosolic Brown Forest (LBF), Low Humic Latosol (LHL), Humic Latosol (HL) and Humic Ferruginous Latosol (HFL) soil groups were constructed using the $Ca(OH)_2$ incubation method described by Yuan[24]. The characteristic properties of these soil groups are given in Table 1.

TABLE 1. Characteristics properties of the different soil groups

Soil Group	pH[1]	% Organic matter[2]	% Clay[3]	CEC[4] (me/100g soil)	Mineralogy[5]
LHL	5.9 ± 0.8	4.7 ± 1.7	6.4 ± 8.3	21.1 ± 8.6	kaol > Goet > Gibb
HL	5.5 ± 0.3	5.5 ± 0.6	54.2 ± 9.0	15.6 ± 2.7	kaol ~ Goet ~ Gibb
HFL	4.8 ± 0.5	8.4 ± 0.6	41.7 ± 11.0	18.0 ± 4.5	Gibb > Goet > Kaol
LBF	5.3 ± 0.4	11.7 ± 3.2	32.5 ± 6.2	23.2 ± 3.4	Gibb > Goet > kaol

1 5:2 water/soil suspension
2 by Walkey-Black method (Metson[13])
3 by pipette method
4 by summation of bases and Al
5 kaol : kaolinite
Gost : Goethite
Gibb : Gibbsite

After treatment with 0.01M H_2SO_4 (Le Roux and de Villiers[10]) or saturated $Ca(OH)_2$ and incubation, the soils were extracted with unbuffered M NH_4Cl as described by Nommik[14]. The concentration of Ca and Mg in the NH_4Cl extracts were then determined by EDTA titration (Heald[4]); the K and Na extracted were read on a flame photometer while the Al was measured by the aluminum colorimetric method of Hsu[5] using ascorbic acid to minimize Fe interference (Jayman and Sivasubramaniam[7]). The cation exchange capacity (CEC) of the soil samples was calculated by summation of the base cations (Ca, Mg, K, Na) and Al in the NH_4Cl extracts.

Sugarcane Field Trials

In order to obtain systematic information on the response of sugarcane to liming in Mauritius, field trials were laid down in 1974 at four experimental sites characterized by a low soil pH (Table 2). Besides the control (no lime) the trials included three levels of lime residue* which were applied at 4.7, 9.5 and 14.2 tons/ha and at three levels of coral sand, namely, 7.1; 14.2 and 21.3 tons/ha. Both the lime residue and the coral sand were applied in the furrows at planting. Each treatment was replicated four times in a randomized block design where each plot consisted of 4 cane rows 12m long each. All the plots received NPK at rates currently recommended for optimum economic yield. The sugar yields obtained from the central two rows of each plot were recorded over a four year period.

TABLE 2. Sugar yields as influenced by liming

Trial Site	Soil Group+	Initial Soil pH	Initial % Ca on exchange complex	Sugar/yield* (Tons/ha) Control	Coral sand (tons/ha) 7.1	14.2	21.3	Lime residue (tons/ha) 4.7	9.5	14.2	LSD 5%	1%
Beau Champ	HL	5.2 ± 0.1	78.1 ± 1.2	10.66	10.23	10.87	10.78	10.39	10.40	9.95	0.68	0.92
St. Julien	LBF	5.6 ± 0.2	77.2 ± 0.5	9.05	8.98	8.86	9.10	9.07	8.51	8.13	0.31	0.42
B. Veine	LBF	5.5 ± 0.1	84.7 ± 0.4	8.44	8.08	7.73	7.44	7.74	8.79	8.47	1.12	1.56
Colmar	LHL	4.7 ± 0.2	80.2 ± 2.2	10.06	8.86	9.69	9.62	9.32	9.98	9.13	1.55	2.15

\+ *No lime trials were performed on acid HFL soils because the proper amendment for these soils, which are invariably deficient in Si, is found to be $CaSiO_3$ and not lime (Ross et al[18]).*

* *Mean over four years*

* *Lime residue, by analysis, contains approximately 25% $CaCO_3$ and 60% $Ca(OH)_2$ while coral sand contains about 90% $CaCO_3$.*

Leaf Analyses

The middle 10 cm section of top-visible dewlap (TVD) leaves, free of midribs, were collected at the peak growth stage of three successive sugarcane ratoon crops and dried at 90°C. The leaf samples were then ground to pass a 0.5mm sieve and digested with a $H_2SO_4/HClO_4$ mixture (Tikhomirova[20]). Following the digestion, N in the leaf was determined by the Nessler colorimetric method (Ward and Johnston[2,3]), K by flame photometry and P as described by Van Schouwenburg and Walinga[22] Manganese and Ca in the leaves were determined, following dry ashing at 500°C for six hours, by the method of Van Schouwenburg[21] and by flame photometry, respectively.

RESULTS AND DISCUSSION

Exchangeable Ca and Al in soils

The results obtained from incubation experiments show that the addition

of lime to the soils markedly increased the Ca saturation of their exchange complex only when the pH was below 5.0 (Fig. 1). At pH values greater than 5.0, liming did not bring about any appreciable increase in the exchangeable Ca status. Above pH 5.0 all the soils studied had in fact more than 70% of their exchange complex occupied by Ca. The low pH values observed in the soils in spite of such a high percentage of exchangeable Ca was apparently due, as indicated by Abruna *et al* [1], to the hydrolysis of exchangeable Al.

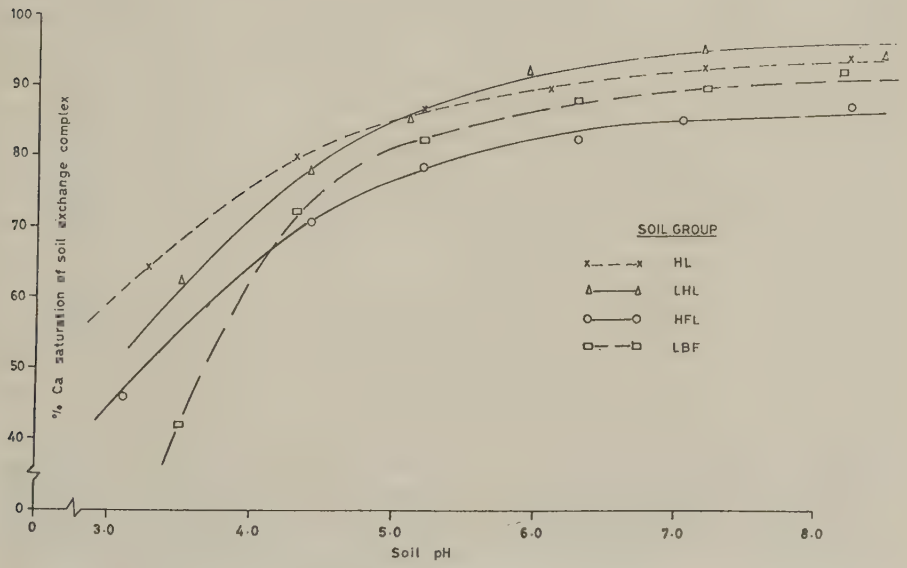

FIGURE 1. Influence of pH on calcium saturation of soil exchange complex

Exchangeable Al in soils on the other hand, decreased drastically with rising pH (Table 3). This is in agreement with observations reported by Hsu[6] . The data obtained indicated that lime application to the soils would reduce the exchangeable Al to negligible values at pH 5.0 and above. It is also apparent from the inverse variation of exchangeable Al with pH that above pH 5.0 soil infertility due to the presence of excessive amounts of Al is unlikely to occur in soils of Mauritius.

Response of Sugarcane to Liming

From the variations of exchangeable Ca and Al with pH (Fig. 1, Table 3) it may be deduced that liming acid soils with pH greater than 5.0 in Mauritius would not improve the fertility of the soils. This inference is supported by the field results obtained. Thus, as illustrated in Table 2, no positive response to liming was obtained irrespective of whether the liming materials were lime residue or coral sand and even though the soil pH at one trial site, namely Colmar was as low as 4.7. On the contrary, high doses of lime residue tended to depress the sugar yield. Indeed at Beau Champ lime residues applied at the rate of 14.2 tons/ha significantly reduced

TABLE 3. Influence of pH on soil exchangeable Al

Soil Group	pH	Exchangeable Al (me/100g Soil)
LBF	3.4 ± 0.1	4.2 ± 0.2
	4.3 ± 0.1	2.0 ± 0.3
	5.2 ± 0.1	0.1 ± 0.0
HFL	3.1 ± 0.1	2.2 ± 0.4
	4.4 ± 0.1	0.6 ± 0.1
	5.1 ± 0.1	0.1 ± 0.1
HL	3.3 ± 0.1	1.5 ± 0.5
	4.3 ± 0.0	0.3 ± 0.1
	5.3 ± 0.2	0.0
LHL	3.5 ± 0.1	1.8 ± 0.7
	4.3 ± 0.1	0.6 ± 0.2
	5.2 ± 0.2	0.0

the sugar yield at the 95% probability level. The decrease in sugar yield as a result of adding lime residue to soil was even more marked at St. Julien where 9.5 tons lime residue/ha was observed to cause a significant reduction in sugar yield at P = 0.01 (Table 2). A significant reduction in sugar yield was however not observed at the highest level of coral sand used. On the basis of the data obtained on the variation of exchangeable Ca with pH (Fig. 1) the failure of sugarcane to respond positively to liming may be ascribed partly to the fact that above pH 5.0 the soils already had a high and satisfactory exchangeable Ca status (> 70% of the CEC) which was not appreciably improved through liming. Poor growth effects due to a low Ca status were in consequence virtually non-existent in the soils at the trial sites. This is supported by the good nutritional Ca status of sugarcane as reflected by leaf analyses (Table 4). Thus, the Ca level in the TVD leaf of the sugarcane was well above the threshold value of 0.13 to 0.15% dry matter (Samuels[19]) even in the control. Furthermore the level of exchangeable Al in the soils, as indicated by the data in Table 3, was too low to adversely affect the growth of the sugarcane. The absence of Al toxicity and the satisfactory Ca status of the soils therefore accounted for the lack of response of sugarcane to liming.

In addition to correcting Al toxicity and low Ca status, lime is commonly applied to acid soils to alleviate P fixation and Mn toxicity. Leaf analyses show that though liming in general reduced the uptake of Mn by sugarcane (Table 4), the reduction in Mn uptake, which was particularly apparent at Colmar, was not accompanied by a concomitant increase in sugar yields (Table 2). This indicates the absence of Mn toxicity in soils at the field trial sites. Moreover since the lower critical level on Mn in TVD leaf of sugarcane is approximately 20 ppm (Samuels[19]), the results of leaf Mn emphasized that sugarcane varieties recommended for humid

TABLE 4. Nutrient status of sugarcane as reflected by third leaf analyses.

Nutrient Element	Trial Site	Nutrient level in third leaf: Lime residue (tons/ha) Control	4.7	9.5	14.2	Coral and (tons/ha) 7.1	14.2	21.3	LSD (5%)
Manganese (ppm)	Beau Champ	58	56	53	52	50	49	46	7
	St. Julien	54	49	52	50	50	50	49	9
	Bonne Veine	52	44	45	42	42	42	42	10
	Colmar	103	70	61	63	70	60	52	25
Calcium (% d.m.)	Beau Champ	0.27	0.27	o.26	0.26	0.28	0.27	0.29	0.03
	St. Julien	0.28	0.30	0.31	0.33	0.30	0.33	0.33	
	Bonne Veine	0.32	0.33	0.33	0.32	0.31	0.32	0.35	
	Colmar	0.30	0.32	0.40	0.38	0.36	0.31	0.35	
Phosphorus (% d.m.)	Beau Champ	0.20	0.20	0.21	0.20	0.20	0.20	0.20	0.01
	St. Julien	0.21	0.21	0.21	0.20	0.21	0.20	0.21	
	Bonne Veine	0.20	0.20	0.21	0.21	0.20	0.21	0.20	
	Colmar	0.20	0.19	0.20	0.19	0.19	0.20	0.19	
Potassium (% d.m.)	Beau Champ	1.14	1.11	1.13	1.11	1.13	1.10	1.12	0.04
	St. Julien	1.12	1.17	1.17	1.18	1.17	1.16	1.14	
	Bonne Veine	1.18	1.15	1.17	1.18	1.17	1.18	1.19	
	Colmar	1.22	1.17	1.22	1.19	1.20	1.22	1.18	

areas of Mauritius can tolerate, without any adverse effects on yield, the presence of a high internal concentration of Mn.

Beneficial effects of liming in the uptake of soil P is related to the correction of toxicity problems (Mendez and Kamprath[12]; Jones and Fox[8]). Since no toxicity of Al or Mn occurred in the soils at the field experimental sites, no beneficial effect of liming on the P uptake by sugarcane should be expected. The P nutritional status of sugarcane as indicated by foliar diagnosis showed that this was indeed the case (Table 4).

While the lack of any positive yield response of sugarcane to liming (Table 2) may be attributed to the absences of Al and Mn toxicities and to the presence of an already high Ca status in soils, the factors responsible for the significant decrease in sugar yield observed at Beau Cham and St. Julien as a result of applying high doses of lime residue are still unclear. Massive liming of tropical soils with low CEC and impoverished native fertility is however known to create nutrient unbalance (Martini *et al* [11]). In this context liming acid soils often results in a decreased availability of K (Godert *et al* [3]). Such a reduction in K availability is not reflected in

the K status of sugarcane in Mauritius. Leaf analyses in fact indicated that the K nutrition of sugarcane in Mauritius is not significantly altered upon liming. (Table 4).

CONCLUSIONS

The present study demonstrates the close relationship that exists among the parameters of pH, exchangeable Ca and Al in the soils. Thus, at pH greater than 5.0, the level of soil exchangeable Al becomes negligible while exchangeable Ca occupies more than 70% of the exchange complex. On account of this close relationship, soil pH acts as a pointer of the exchangeable Ca and Al status of the soils. Soil pH can therefore continue to be used as a reliable criterion for determining the need to lime acid soils under sugarcane in Mauritius. In this respect, with Ca being added to soils in Mauritius in appreciable quantities as incidental components of N and P fertilizers, e.g. calcium ammonium nitrate, triple superphosphate, liming only becomes an indispensable practice to neutralize exchangeable Al at pH below 5.0. Liming recommendations should therefore be aimed towards raising the soil pH to 5.0 or 5.5.

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ENCALAMIENTO DE SUELOS DE CAÑA DE AZUCAR EN MAURICIO

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RESUMEN

Se estudió las variaciones en Ca y Al intercambiable con pH y se utilizó para explicar las respuestas en rendimiento de caña de azucar al encalamiento de suelos acidos en Mauricio.

El encalamiento no mejoró el rendimiento de caña de azúcar. Esto se pudiera atribuir a la ausencia de toxicidad de Al y Mn y la presencia de una buena cantidad de Ca en los suelos. Investigaciones de suelos mostraron que bajo un pH mayor de 5.0 el Al intercambiable fue reducido a valores insignificantes mientras que el Ca intercambiable ocupaba más del 70% de los sitios de intercambio catiónicos y aparentemente no aumentó al ser encalado. Altas dosis de cal pudieron deprimir los altos rendimientos de caña de azúcar. La razón por la cual los efectos del encalado resultan adversos en Mauricio es inexplicable.

Debido a la estrecha asociación que existe entre pH y Ca y Al intercambiable, el encalado de suelos ácidos en Mauricio solamente debe ser una práctica indispensable al ser el pH del suelo menos de 5.0. Las recomendaciones del encalado por lo tanto se deben dirigir a levantar el pH hasta 5.0 ó 5.5.

FERTILIZER MANAGEMENT IN SUGARCANE RATOON

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ABSTRACT

Three experiments were conducted at Philsucom La Granja Station to determine the influence of nitrogen level applied at plant crop on the performance of ratoon crop and determine the best age to ratoon and the proper timing of nitrogen application for ratoon crops. The experiments were carried out for one plant crop and one ratoon crop.

The results of the three experiments revealed that ratooning did not affect Piculs Sugar per ton cane (Picul = 63.25 kg) of varieties Phil 6607, Phil 56226 and Phil 5333 but considerably decreased tonnage in one experiment particularly that of ratoon of three varieties. It is rather the rate of nitrogen applied at ratooning that was the major factor in increasing tonnage. The performance of ratoon crop is profoundly influence by the age of the plant crop at ratooning. At various rates of nitrogen applied to the ratoon crop, piculs sugar per ton cane, ton cane per hectare and picul sugar per hectare increased linearly only for ratoons from 11-month old plant crop. In general, the performance of ratoon is influenced less by nitrogen applied to the plant crop but more affected by the amount and timing of N fertilization in ratoon crop, age of the plant crop at ratooning and variety planted.

INTRODUCTION

Ratooning of sugarcane is a universal practice for economic reasons. One ratoon following the plant crop is common in the Philippines, but Pao[5] reported as many as 9 ratoons in Taiwan.

Reports on yield performance between plant and ratoon crops are conflicting. Panol[4] obtained higher sugar yield, but Ferraris, *et al*[2] obtained lower sugar yield in plant than ratoon crops. These discrepancies in results can be attributed to differences in climatic conditions prevailing in the plant crop grown a year ahead of the ratoon crop, variety, fertilization, and occurrence of pests and diseases. Supplying adequate water and proper amount of fertilizer during the critical growth period seems to be the most important measures in increasing the crop of ratoon (Pao[5]). Also, Panol's[4] concept of break-even

yield differential provides a good basis in deciding to ratoon or not.

In Hawaii emphasis is given to controlling nitrogen in the cane during its life, maintaining adequately high levels during the first few weeks of growth and ending up eventually at low levels at the time of harvest for sucrose control juice (Humbert[3]). The common approach in Mauritius is early application in a single dose (Parish[6]).

Davies and Vlitos[1] reported higher response of ratoons than plant crop to applied nitrogen in Mauritius and found split application more beneficial for ratoons. In the Philippines nitrogen is also usually split for both plant and ratoon crops. The first application is within the first month and the second within the next two or four months after planting or ratooning. In Taiwan higher yields are reported when total dose is applied 3-4 months after planting (Srivastava[7]).

The present study was conducted to (a) determine the performance of the ratoon crop as influenced by nitrogen fertilization and harvest age of the ratoon crop of three sugarcane varieties, (b) compare yield performance and evaluate nitrogen requirements of plant and ratoon crops, and (c) study timing of nitrogen fertilization in ratoons.

MATERIALS AND METHODS

Three sets of experiments were conducted simultaneously at La Granja Experiment Station in 1977-79 using Phil 56226, Phil 5333 and Phil 6607. All three experiments were laid out in split plot design. Each experimental unit measured 5 x 5 m.

In experimental 2 the same three varieties were planted at staggered dates to one month interval and harvested simultaneously to correspond to 10, 11 and 12 months at ratooning. The plant crop was fertilized with 60, 120 and 180 kg N/ha but the ratoon received a uniform application of 180 kg N/ha soon after stubble shaving.

In experiment 3 the plant crop was uniformly fertilized with 180 kg N/ha, one half at planting and the other half 3 months later. For the ratoon, N was applied at 90 and 180 kg/ha according to the following schedule:

A – full dose, one week after harvest
B – full dose, four weeks after harvest
C – full dose, seven weeks after harvest
D – full dose, ten weeks after harvest
E – 1/2 dose at one week, 1/2 dose at four weeks after harvest
F – 1/2 dose at one week, 1/2 dose at seven weeks after harvest
G – 1/2 dose at one week, 1/2 dose at 10 weeks after harvest

RESULTS AND DISCUSSION

Performance of plant and ratoon crops

Average tonnage and sugar yields of three sugarcane varieties for both plant and first ratoon crops are presented in Table 1. Ratooning did not affect sugar rendement. However, tonnage of all three varieties were significantly lower in ratoon than plant crop in Experiment 1 although similar in Experiment 2. The most adversely affected was Phil 56226 and the least was Phil 5333. Consequently, Phil 56226 had the lowest tons sugar per hectare for ratoon in Experiment 1.

TABLE 1. Tonnage and sugar yields of plant and ratoon crops of three sugarcane varieties.

Variety	Expts.	ton cane/ha		picul sugar/ton cane		picul sugar/ha	
		PC	RC	PC	RC	PC	RC
Phil 6607	1	116	83	1.71	1.77	205	149
	2	122	122	1.51	1.49	181	182
	average	119	103	1.61	1.63	193	166
Phil 5333	1	90	77	1.88	1.86	169	144
	2	116	119	1.61	1.60	185	185
	average	103	98	1.75	1.73	177	162
Phil 56226	1	112	60	1.80	1.95	201	120
	2	91	90	1.71	1.70	154	154
	average	102	75	1.76	1.83	178	137

PC – plant crop; RC – ratoon crop

The results indicate that ratoon yields can be as good as or inferior to plant crop. Under favourable conditions tonnage drops remarkably while sugar per ton cane remains unaffected. The three varieties can be graded as follows in ratooning ability: Phil 5333 > Phil 6607 > Phil 56226.

Influence of nitrogen fertilization

The effects of nitrogen applied at the plant crop and at ratooning on ton cane per hectare and sugar per ton cane are given in Table 2. Derived data on sugar per hectare are not reported here because they generally follow the same trends as the cane per hectare.

As a whole nitrogen fertilizers applied to the plant crop harvested at 12 months old did not exert any influence on tonnage of Phil 6607, Phil 56226 and Phil 5333. The rate of nitrogen applied at ratooning was more important in increasing tonnage. Phil 6607 and Phil 5333 responded more to increasing level of applied nitrogen at ratooning than Phil 56226 when the plant crop received 60 kg N/ha.

Sugar per ton cane of Phil 5333 decreased remarkably at 180 kg N/ha in plant crop. Those for Phil 6607 and Phil 56226 were not affected.

On the average high sugar production of first ratoon of three varieties were obtained with application of 180 kg N/ha regardless of the nitrogen history of the plant crop. Yield data for the plant crop also showed highest sugar per hectare at 180 kg N/ha.

Timing of nitrogen application

Response of three varieties to full dose and split applications, as well as timing of these applications, differed for two rates of N applied. The data are shown in Table 3. With the single applications sugar per hectare was similar for 90 and 180 kg N/ha for three varieties. When nitrogen was split, Phil 5333 produced lower sugar per hectare at 90 kg N and Phil 6607 produced higher sugar per hectare at 90 than 180 kg N/ha, while sugar yields of Phil 56226 were similar for the two nitrogen rates.

TABLE 2. Tonnage and rendement of first ratoon of three sugarcane varieties under different nitrogen fertilizer management.

Kg N/ha (plant crop)	kg N/ha (ratoon)	Phil 6607		Phil 56226		Phil 5333	
		TC/ha	PS/TC	TC/ha	PS/TC	TC/ha	PS/TC
60	60	72.7	1.72	58.7	1.96	59.3	1.84
	120	84.2	1.68	58.0	2.01	84.5	1.86
	180	90.7	1.92	63.2	1.89	87.7	1.89
	average	82.5	1.77	59.9	1.95	77.2	1.86
120	60	66.1	1.78	56.1	2.06	67.2	1.88
	120	87.0	1.73	52.3	1.94	67.2	1.86
	180	87.4	1.73	50.0	1.93	76.1	1.79
	average	80.2	1.75	52.8	1.98	70.2	1.84
180	60	72.9	1.64	58.1	1.84	73.3	1.83
	120	79.5	1.77	58.0	2.03	77.4	1.96
	180	86.5	1.79	71.8	2.11	85.1	1.77
	average	79.6	1.73	62.6	1.99	78.6	1.85

In this experiment, Phil 6607 and Phil 56226 responded only up to a level of 90 kg N/ha. Best yields were obtained when 90 kg N/ha was applied in one application at 10 weeks after stubble shaving for Phil 56226 and during the first seven weeks after stubble shaving for Phil 6607 or when split at 1 and 4 weeks after stubble shaving.

Tons cane per hectare (TC/Ha) and sugar per hectare of Phil 5333 were significantly higher at 180 kg N applied in single application after stubble shaving or split at 1 and 4 weeks after stubble shaving. At 90 kg N/ha reasonably

TABLE 3. Influence of time of nitrogen fertilization after stubble shaving on yield performance of first ratoon of three sugarcane varieties.

Variety	N kg/ha	Single Dose					Split Dose			
		1 WAS[1]	4 WAS	7 WAS	10 WAS	Ave.	1/4 WAS[2]	1/7 WAS	1/10 WAS	Ave.
						TC/HA				
Phil 56226	90	65.3	68.6	67.0	84.4	71.3	81.2	71.4	71.6	74.1
	180	62.8	68.9	74.5	63.4	67.4	76.2	73.3	79.1	76.2
5333	90	74.1	96.3	95.7	99.3	91.3	65.9	72.4	93.6	77.3
	180	119.1	75.9	97.4	89.4	95.4	103.8	81.4	98.6	94.6
6607	90	108.5	91.1	95.3	80.4	93.8	105.9	83.6	104.3	97.9
	180	116.5	102.5	101.0	91.5	102.9	87.1	99.5	94.1	93.6
						PS/TC				
Phil 56226	90	1.71	1.81	1.78	1.67	1.74	1.87	1.79	1.84	1.83
	180	1.80	1.85	1.85	1.77	1.81	1.88	1.78	1.81	1.82
5333	90	1.60	1.62	1.65	1.66	1.63	1.68	1.57	1.68	1.64
	180	1.61	1.69	1.54	1.60	1.61	1.64	1.77	1.63	1.68
6607	90	1.59	1.69	1.49	1.59	1.59	1.72	1.62	1.64	1.66
	180	1.17	1.48	1.48	1.49	1.41	1.65	1.53	1.49	1.56
						PS/HA				
Phil 56226	90	111.5	123.7	119.0	140.7	123.7	152.0	127.3	132.0	137.1
	180	113.2	127.5	137.7	112.4	122.7	143.5	130.1	143.5	139.0
5333	90	118.7	155.8	157.7	164.7	149.2	110.6	112.9	156.6	126.7
	180	191.4	128.2	149.8	142.5	153.0	170.0	144.0	160.1	158.0
6607	90	171.0	152.9	141.5	127.4	148.3	182.1	135.1	171.7	162.9
	180	135.8	151.8	149.3	135.5	143.3	142.7	151.6	140.1	144.8

1 *WAS — weeks after stubble shaving*

2 *Numerator is week of first application and denominator is week of second application after stubble shaving.*

high yields were also obtained when split at 1 and 10 weeks or applied full dose during 4 to 10 weeks, after stubble shaving.

The beneficial effects of later applications of N to Phil 56226 maybe attributed to the slower growth of this variety at an early stage compared to Phil 6607 and Phil 5333. It should be remembered, however, that efficiency of nitrogen fertilization is most effected by moisture status of the soil and a fixed schedule of single or split applications would not be a sound guide.

As shown in Fig. 1 tons cane per hectare, height of stalk and sugar per hectare of first ratoon of Phil 6607, Phil 5333 and Phil 56226 harvested at 12 months old were lowest when the plant crop was harvested at 10 months

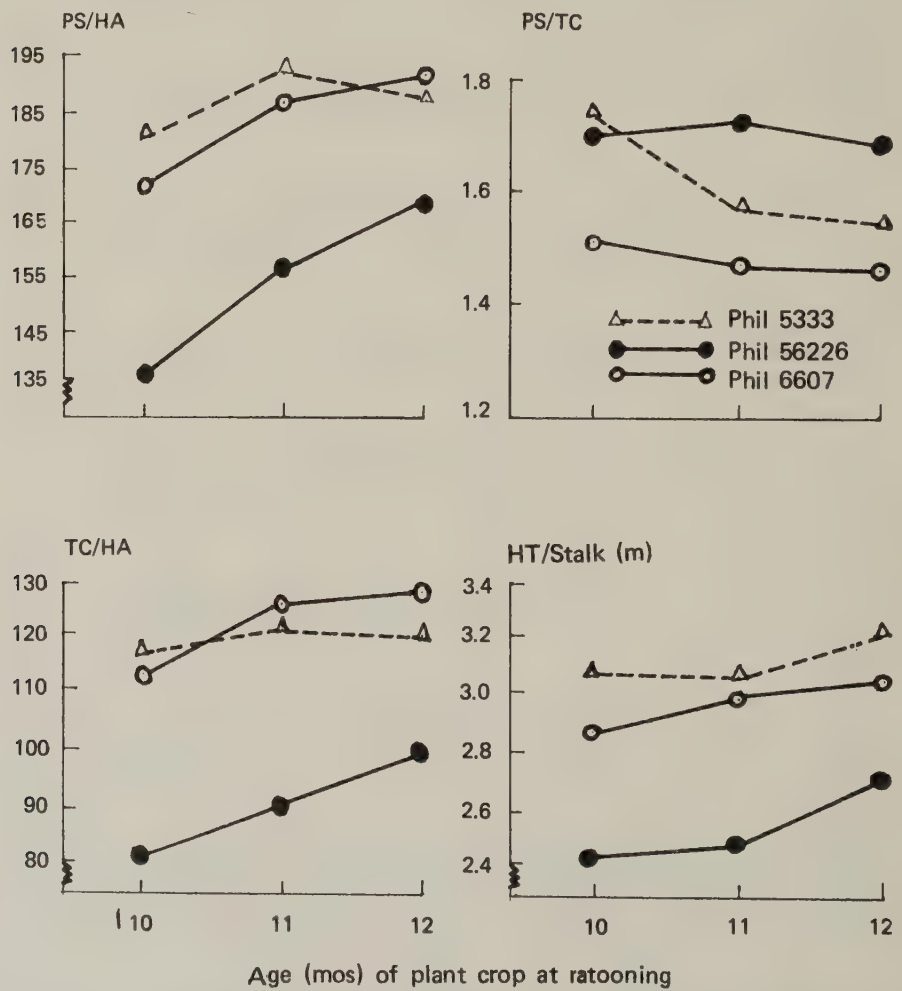

FIGURE 1. Yield performance of 12-month old first ratoon of three varieties of sugarcane as influenced by harvest age of plant crop.

old. These characteristics improved, particularly with Phil 56226, as the age of the plant crop reached 12 months at the time of ratooning. Sugar per ton cane of Phil 56226 was not affected, but that of Phil 6607 and Phil 5333 were lower at 11 and 12 months. The biggest decrease in picul sugar per ton cane occurred between ratoons of Phil 5333 from 10-months and 11-months old plant cane.

Influence of age at ratooning and nitrogen rates on tonnage and sugar yields are illustrated in Fig. 2. Linear responses to applied nitrogen were obtained only with varieties ratooned from 11-month old plant crop. For 12-month old plant crop the best yields were obtained at the lowest 60 kg N/ha. This is due to reduction in sugar per ton cane and ton cane per hectare at higher rates and perhaps decrease in number of millable stalks when the crop is harvested at 12 months as is the case in this experiment.

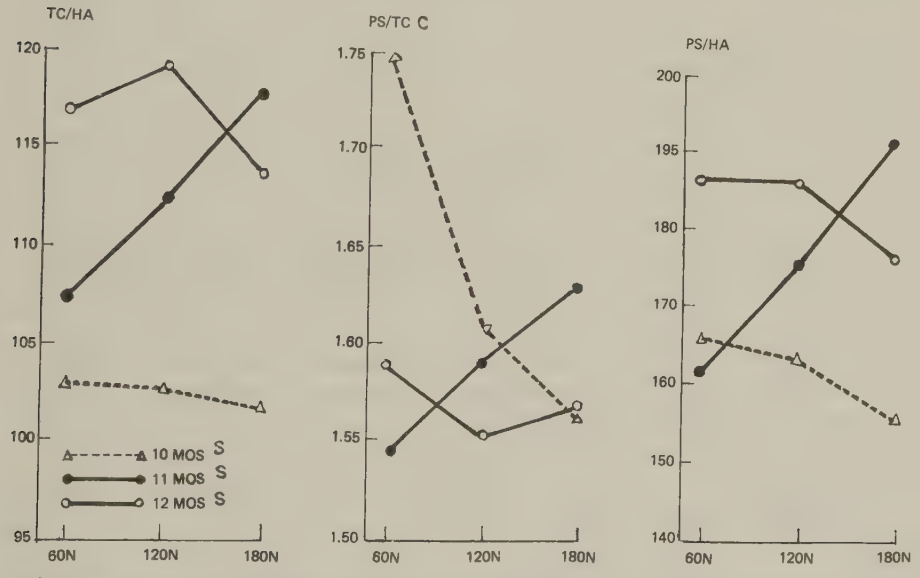

FIGURE 2. Sugar and tonnage yields of first ratoon as affected by nitrogen fertilization and harvest age of plant crop.

CONCLUSION

Ratooning did not affect sugar per ton cane of Phil 6607, Phil 56226 and Phil 5333 but considerably decreased tonnage in one experiment, particularly of Phil 56226. Results of all three experiments showed that picul sugar per ton cane is highest in Phil 56226 followed by Phil 5333 and Phil 6607. Picul sugar per hectare of Phil 6607 and Phil 56226 were comparable in plant crop, but the latter was significantly lower in ratoon crop.

Nitrogen applied in the plant crop did not affect tonnage of ratoons of three varieties. The rate of nitrogen applied at ratooning was a major factor

in increasing tonnage. Sugar per ton cane of Phil 5333 was more sensitive to high N rates applied to ratoon when the plant crop also received high rates of nitrogen. The response of the varieties to various timing of single and split applications of N differed and such behavior appears to be related to growth characteristics of the varieties at early stage.

The performance of ratoon crops is profoundly influenced by the age of the plant crop at ratooning. Ratoons of Phil 56226 produced the highest tons cane per hectare and tons sugar per hectare from 12-months plant crop and Phil 6607 and Phil 5333 from 11-months plant crop. At various rates of nitrogen applied to the ratoon crop, sugar per ton cane, ton cane per hectare and sugar per hectare increased linearly only for ratoons of 11-months old plant crop.

Based on these results, performance of ratoons is influenced less by the nitrogen applied to the plant crop but is more affected by the amount and timing of nitrogen fertilization in ratoon crop, age of the plant crop at ratooning and variety planted.

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MANEJO DE FERTILIZANTE EN RETOÑOS DE CAÑA DE AZUCAR

E. P. Gotera, R. M. Tapay, M. O. Araneta y W. G. Espada

RESUMEN

Se realizaron tres experimentos en la Estacion Philsucom La Granja para determinar la influencia del nivel de N aplicado a la plantilla sobre el rendimiento del retoño y determinar la mejor edad para retoñar y el tiempo preciso para aplicar nitrógeno a los retoños. Los experimentos se llevaron a cabo durante una plantilla y un retoño.

Los resultados de los tres experimentos mostraron que el retoñamiento no afectó las PA/TC de las variedades Phil 6607, Phil 56226 y Phil 5333 pero disminuyo considerablemente el tonelaje en un experimento particularmente el de Phil 56226. El nitrógeno aplicado a la plantilla no afectó el tonelaje de los retoños de tres variedades. En mas bien la dosis de nitrógeno aplicada al retoño el principal factor responsable de aumentar el tonelaje. El rendimiento del retoño es profundamente afectado por la edad de la plantilla a ser retoñada. A varias dosis de nitrógeno aplicada el retoño, PA/TC, TC/ha y PA/ha aumentaron linealmente solamente para retoños de plantillas de 11 meses. En general, el rendimiento de los retoños es afectado menos por el nitrogeno aplicado a la plantilla y mas por la cantidad y tiempo de fertilizacion del N en los retoños, edad de la plantilla al retoñar y variedad sembrada.

SUGARCANE FERRIC CHLOROSIS IN EXCESSIVE CALCAREOUS SOILS

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ABSTRACT

The study has been carried out to determine the influence of total and active $CaCO_3$ of the soil on growth and production of sugarcane, and particularly on the nutrients present in sugarcane leaves.

The results showed that the effect of $CaCO_3$ varied depending on the organic matter level of the soil and the presence of water table near the soil surface.

These conditions influenced the degree of solubility of interchangeable ferrous iron, making it possible to reduce high levels of $CaCO_3$.

With low levels of organic matter and no water table, the critical levels of total $CaCO_3$ in soil were between 1.50 to 2%. Severe damage occurred at above 3%. Shown as active $CaCO_3$ these levels went from 1 to 1.50%. Severe damage was present at above 1.50%.

With high levels of organic matter and the water table present, sugarcane culture got along well with average values of 10% for total $CaCO_3$ and 4.80% for active $CaCO_3$.

Potential REDOX of soil diminished when water table was present and the value of interchangeable ferrous iron in the soil increased. There were evident alterations in the concentration of nutrients in the leaves as a consequence of $CaCO_3$, together with a marked chlorosis as $CaCO_3$ increased in soil.

This situation did not happen in soils with a high content of organic matter and water table.

INTRODUCTION

Sugarcane is the most important crop cultivated in the North West of Argentina from the economic point of view. The area planted is under a variety

of climatic and soil conditions. Areas in Tucuman, Salta and Jujuy for example, have soil conditions which may not favor sugarcane growth.

Among the most important problem is of ferric chlorosis which is caused by the presence of excessive quantities of calcium carbonate in soils with high pH.

The symptoms of chlorosis are produced by a reduction of the chlorophyll contents in the foliar tissue and are especially detected in the fibro-vascular bundles along the leaf. This is known as intervein chlorosis which in severe cases, makes the whole leaf turn whitish, showing brown patches ending in necrosis, mainly in the tips and edges.

Various authors have studied the effect of ferric chlorosis in plants and the actions of bicarbonate ion and calcium excess in soil have been pointed out as some of the most common causes. The deficiency of iron in such soils therefore, is usually a consequence of insolubility rather than lack of the said soil nutrient.

According to Humbert[9], insolubility is evident on the surface of chloroplast where the chlorophyll is formed.

Even when iron does not constitute the chlorophyll molecule, it is essential for its synthesis since it works on the formation of a specific kind of ribonucleic acid which, in turn, regulates the chlorophyll synthesis.

That is why when being immobilized in the plant, there is as much or more total iron in the chlorotic leaves than in the green ones. Nevertheless, the problem of ferric chlorosis is not confined to direct dependence on $CaCO_3$ but also on something which is more complex, such as the relationship of iron reduction-oxidation in soil, since iron will be more or less soluble and its assimilation by sugarcane will also be higher or lower.

A typical example of this occurs in humid areas of soils with poor drainage and high quantities of calcium carbonate on the profile with non-saline superficial water table. This as a whole, makes the regular development of cultivation without symptoms of chlorosis possible.

Excess calcarecus as a consequence of pedogenesis of the soil and the effect of high contents of $CaCO_3$ in the presence of water table close to surface were both given remedies.

In both cases, tentative critical limits to $CaCO_3$ levels appropriate for adequate growth of sugarcane in terms of height, number and weight of millable stalks and quality of juice were determined.

Little has been done before regarding critical levels of sugarcane tolerance to $CaCO_3$.

The present work also deals with nutrient concentration in sugarcane

leaves as regards to the presence of calcium carbonate.

MATERIALS AND METHODS

Between 1973 and 1976, various plots were chosen in both provinces of Tucuman and Jujuy where sugarcane showed effects of marked leaf chlorosis.

Following Thorntwaite water balance, the plots in Tucuman were between sub-humid to dry sub-humid. No cases of semi-arid conditions were recorded.

According to Koppen classification, all plots in Tucuman had a climate of the "c W a" type.

From each plot, soil samples were taken from up to 90 cm deep between July and September. The sample of whole canes for analysis of juice quality and nutrient contents in leaves were also taken. The foliar samples composed of leaves + 1, were also taken during summer in the months of active plant growth.

Measurements of height and weight of stalks from affected and normal neighboring areas with sugarcane plantations of the same variety and age, were taken.

Soil analyses on texture using the pipette method were made. Also determined were pH soil:water relationship 1:2.5 and in saturated mixture by potentiometry method; by organic matter method by Walkey Smolik; total calcium carbonate by volumetric method with Scheiber calcimeter and the active by extraction with ammonia oxalate N/5 and further determination of carbonates by gaseometry by Nijenshon and Pizarro[13].

Cation exchange capacity and exchangeable cations were determined according to Richards[15] for calcareous soils and according to Jackson technique[10] for exchangeable ferrous iron (Fe^{++}).

Water test was made following techniques by Richards. Sucrose analyses were made using methods conventional for sugar industry; the brix was measured by hydrometry, pol by polirizing a substance clarified with dry basic lead acetate (Horne), pol % cane by multiplying juice pol % x 0.81 and reducing sugars by titration according to Lane-Eynon. Purity and rendement were estimated.

Total salt analysis was made by conductivity values. The leaves for analysis were washed off with detergent and water, rinsed with distilled water and dried at 60-70°C.

The portion taken for Fe and Mn analysis was hand pulverized, and the rest which was used for N, P, K, Ca and Mg determination, was ground in Wiley mills through mesh No. 40. The analitical techniques were described by Ward and Johnston[20]. Total chlorophyll was determined calorimetrically, following the Guthrie method.

Redox potential was determined according to Heese[8].

RESULTS AND DISCUSSION

Problems caused by calcareous without the presence of water table.

The results of soil analysis in different plots with sugarcane chlorosis problems are shown in Table 1.

Taking into account the surface horizon, it can be inferred that starting from average values of 1.50 to 2% soil, total calcium carbonate begins to cause chlorosis manifested in the reduction in the growth of stalks which become more severe when the values were about 3%.

Expressed as active calcium carbonate, the critical levels were lower. From 1 to 1.50%, there were problems for sugarcane, together with the classical symptoms of chlorosis becoming more critical at 1.50 to 2%.

PH values in agreement with these cases indicated that signs of ferric chlorosis were manifested from pH 7.5, being more evident from pH 8 onward.

The contents of total and active $CaCO_3$, beside the pH, were higher in plots from La Aguadita, where the biggest reduction in growth and weight of millable stalks was found (Table 5).

These cases coincide with wavy profiled soils subject to dangers of hydric erosion and calcareous outcrop, because of their scanty organic matter which would make that situation even more critical.

There was total absence of soluble salts in all analyzed samples. On account of this, the limiting problem is reduced to only excess of calcareous.

Caimancito (Jujuy) recorded the lowest reductions in height and weight of stalks due to calcium carbonate (Table 5).

In Fig. 1, the negative and highly significant correlation between $CaCO_3$ of soil and height of stalks is outstanding. With active $CaCO_3$, there were no significant levels. From Fig. 1, we gather that with 2% of $CaCO_3$, the reduction in height was 23%, and with 4% it reached 50%.

Problems found at Caimancito and La Aguadita were inherent to pedologic constitution of soil, while at Delfin Gallo and El Naranjo they were "incorporated" problems since, apparently, they were caused by remainders of old buildings in the Argiudol type of soil since calcareous can normally be found deeper in those soils.

A similar case was formerly detected in plots from El Colmanar Agricultural Experiment Station, where total values of $CaCO_3$ for normal growth of sugar-

TABLE 1. Average values of summarized analysis of soils in sites with calcareous problems.

Analysis	Condition of the culture	Caimancito (Jujuy)			La Aguadita (Tucuman)			Delfin Gallo (Tucuman)		El Naranjo (Tucuman)		
		0-20 cm	20-40 cm	40-60 cm	0-30 cm	60-90 cm	0-40 cm	0-40 cm	40-60 cm	0-30 cm	30-60 cm	60-90 cm
Actual pH	good	6.6	6.6	6.5	8.0	8.0	8.2	7.0	7.0	7.4	7.0	7.0
	affected	7.7	7.8	7.8	8.1	8.2	8.3	7.7	7.5	7.7	7.7	7.8
Organic Matter	good	2.00	1.27	1.10	1.89	1.75	1.40	2.76	1.71	3.93	2.90	*
	affected	2.09	1.48	1.12	1.31	0.93	*	3.25	1.82	3.46	2.51	*
Total $CaCO_3$	good	0.14	0.04	0	1.43	0.80	0.14	0.94	0.47	0.08	0.02	0.05
	affected	2.52	2.11	2.07	5.30	4.99	5.06	3.41	1.47	1.45	1.24	0.39
Active $CaCO_3$	good	0	0	0	0.72	0.33	0.08	0.72	0.32	0	0	0
	affected	1.45	1.25	1.25	1.94	1.66	1.43	1.46	1.56	0.96	0.63	0.23

**Analysis not performed*

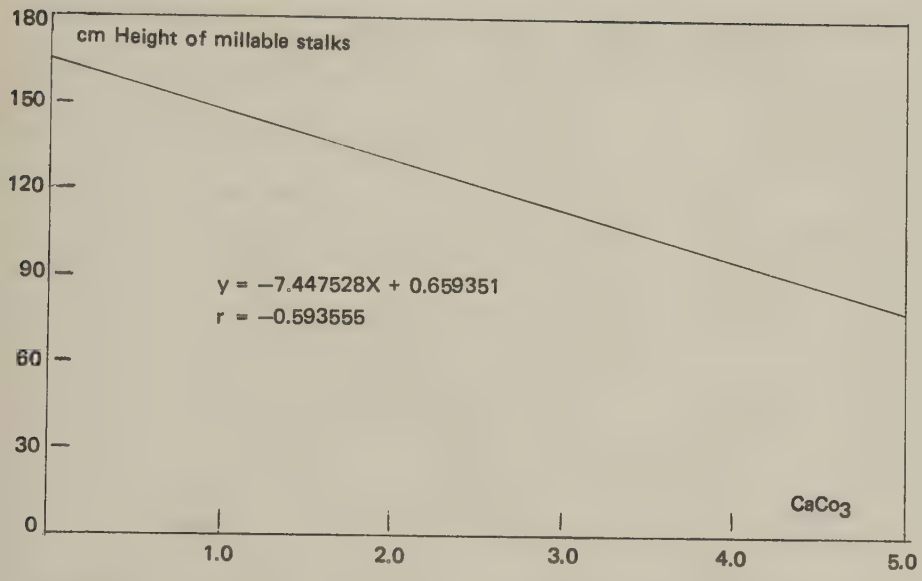

FIGURE 1. CO_3 vs height

cane was under 1.60% with the damage being very severe above 8%, Fogliata[6].

There is an outstanding reduction in chlorophyll contents of sugarcane leaves as total and active calcareous of soil increase. Together with this, iron metabolism in plant becomes more severe.

Table 2 shows chlorophyll values in blades, midribs and rolled spin leaves, expressed as mgr/gr of fresh matter. It can be pointed out that values of chlorophyll in blades + 1 (higher than 2 mgr/gr) ensure a normal photosynthetic activity for an adequate production of sucrose in this culture. Aguadita has been the only case with similar values for the three stages in the analysis of midribs. This is due to the fact that the back side of the midrib was the portion of the leaf which remained green because of the greater concentration of fibrovascular bundles.

Fig. 2 (a and b) shows the statistical relationship between total and active $CaCO_3$ vs. chlorophyll in leaves. Both correlations were negative and highly significant, which makes evident that while calcareous increases, chlorophyll reduces itself. Out of both relationships the closest association among the studied variables was given with active $CaCO_3$.

This is consistent with the French notion applied to vine culture in the sense that the lack of correlation between the total $CaCO_3$ of soil and its power for forming "chlorosis" caused the development of the active $CaCO_3$ conception (Nijenshon[14]).

According to the data from Fig. 2, there was a 50% reduction in the chlorophyll contents in blades when total $CaCO_3$ reached 2.50% and active $CaCO_3$ is 0.908.

TABLE 2. Chlorophyll contents in sugarcane leaves shown as mgr/gr of fresh matter (Average of 3 repetitions for each test)

La Aguadita (Tucuman)
NA 56-79

Blades			Nervures		
Normal	Fairly Chlorotic	Chlorotic	Normal	Fairly Chlorotic	Chlorotic
2.15	1.83	0.81	0.53	0.65	0.57

Caimancito (Jujuy)
NA 56-83

Blades		Nervures		Rolled spin leaves	
Normal	Fairly Chlorotic	Normal	Chlorotic	Normal	Chlorotic
2.20	0.10	0.57	0.17	0.64	0.27

Quality of juice has been inferior in all cases with chlorosis (Table 5). This may be related to the lesser quantity of photosynthesis element available in the leaves.

Hart and Burr[7] found that when the chlorophyll content in sugarcane leaves was less, the rate of photosynthesis was markedly reduced.

Variations in nutrient contents of leaves are given in Table 3.

Total nitrogen in blades decreased in all cases except for La Aguadita which kept the same value. There was a trend to increase nitrogen in the veins of chlorotic leaves, a fact which was more marked in rolled spin leaves.

In fruit and forest trees, the foliar N increased in chlorotic leaves (Aso[2] and Nijenshon[14]). Phosphorus present in chlorotic blades and rolled spin leaves increased in all cases. This is one of the common symptoms which normally go together with ferric chlorosis induced by calcium. The greater absorption of phosphorus under these contributes to the chlorosis inactivating iron internally, (Nijenshon[14]).

The most important cases are those for potassium and calcium since in many crops, there is an increase in K and a decrease in foliar K.

In sugarcane with chlorosis, the increase in potassium were remarkable in chlorotic blades and rolled spin leaves, as compared with the data from the control plants. Ca tended to decrease in blades but not in rolled spin leaves.

TABLE 3. Average values of foliar analysis in testing affected soils with calcareous excess in blades +1, midribs and rolled spin leaves

La Aguadita (Tucuman)	N%	P%	K%	Ca%	Mg%	Fe ppm	Mn ppm	Fe Mn	K/ Ca	K/Ca +Mg	P/ Fe
Normal blade	1.91	0.153	1.00	0.333	0.056	61	58	1.05	3.00	2.57	25
Medium chlorotic blade	1.73	0.168	1.12	0.300	0.069	51	59	0.86	3.73	3.03	33
Chlorotic blade	1.99	0.185	1.95	0.243	0.075	45	49	0.92	8.02	6.13	41
Normal nervure	0.78	0.091	1.37	0.154	0.025	28	45	0.62	8.89	7.65	32
Medium chlorotic nervure	0.77	0.087	1.46	0.185	0.037	32	45	0.71	7.89	6.57	27
Chlorotic nervure	0.96	0.093	1.85	0.158	0.046	43	39	1.10	11.70	9.06	22
Normal rolled spin leaf	1.21	0.203	1.85	0.139	0.055	48	64	0.75	13.31	9.53	42
Medium chlorotic rolled spin leaf	1.43	0.209	1.92	0.152	0.071	61	64	0.95	12.63	8.61	34
Chlorotic rolled spin leaf	1.73	0.219	2.25	0.159	0.076	76	60	1.27	14.15	9.57	29
Delfin Gallo (Tucuman)											
Normal blade	2.65	0.165	1.26	0.438	0.077	94	–	–	2.87	2.44	17
Chlorotic blade	2.46	0.165	1.50	0.406	0.076	70	–	–	3.69	3.11	23
Normal nervure	1.40	0.123	2.50	0.344	0.042	68	–	–	7.27	6.47	18
Chlorotic nervure	1.10	0.080	2.20	0.290	0.036	42	–	–	7.59	6.75	19
Normal rolled spin leaf	1.76	0.212	2.46	0.264	0.048	82	–	–	9.32	7.08	26
Chlorotic rolled spin leaf	1.93	0.239	2.60	0.284	0.060	56	–	–	9.15	7.56	43
Caimancito (Jujuy)											
Normal blade	2.21	0.201	1.62	0.452	0.102	85	64	1.33	3.58	2.92	24
Chlorotic blade	2.11	0.251	2.21	0.484	0.120	105	39	2.69	4.56	3.66	24
Normal nervure	1.02	0.138	1.94	0.211	0.057	46	55	0.84	9.19	7.24	30
Chlorotic nervure	1.05	0.122	1.99	0.290	0.070	84	40	2.10	6.86	5.53	14
Normal rolled spin leaf	1.64	0.209	2.15	0.457	0.070	70	–	–	4.70	4.08	30
Chlorotic rolled spin leaf	1.86	0.236	2.30	0.563	0.080	70	–	–	4.08	3.58	34

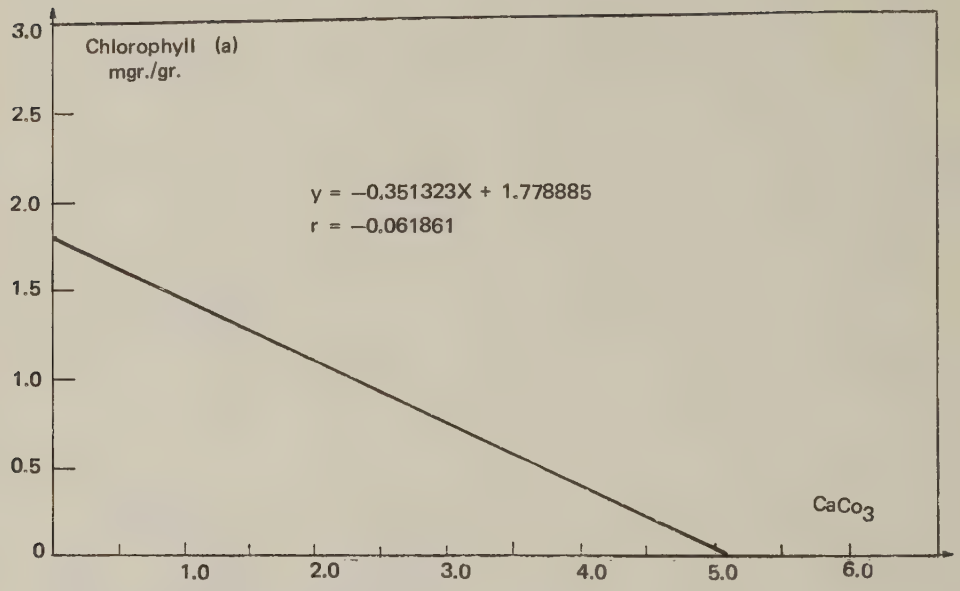

FIGURE 2a. Chlorophyll vs CO_3

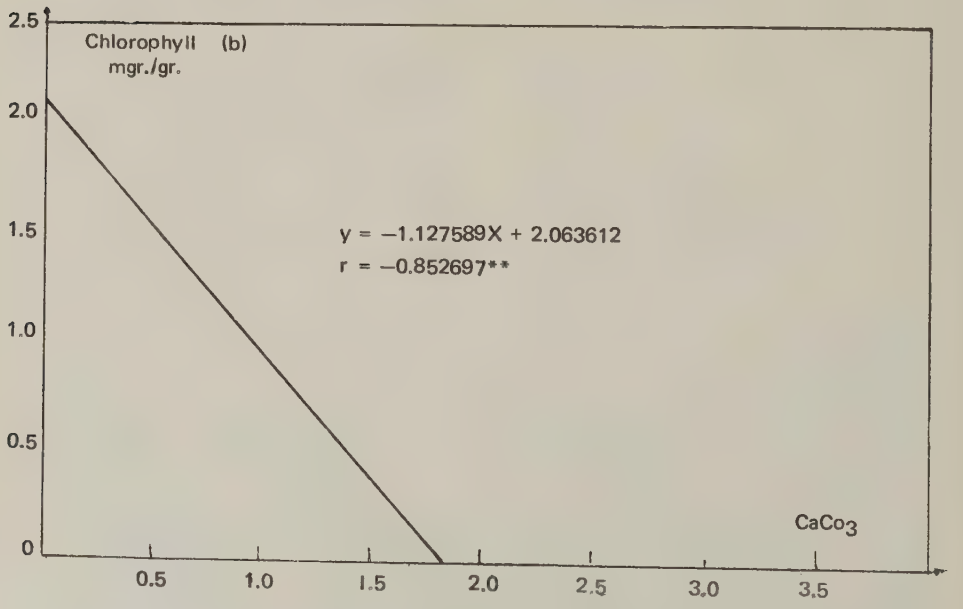

FIGURE 2b. Chlorophyll vs CO_3

Mg as well as P showed a definite tendency to rise as the chlorosis increased. Inspite of greater Mg absorption (and since Mg is a constituent element of the chlorophyll molecule), its presence did not stop the inhibitory effect and lack of iron in chlorophyll synthesis.

The level of iron concentration in the leaves was variable. Fe in chlorotic leaf blades were low as found in the Tucuman sites. In Jujuy, minor Fe content was found in green leaves.

The results found at Caimancito conforms with the concept that ferric chlorosis can be a problem of immobility rather than lack of it.

Iron in the midribs of chlorotic leaves were higher than in normal leaves at La Aguadita and Caimancito.

This is so since that portion of the leaf has the highest concentration of fibrovascular bundles which posses the rings of cells carrying chlorophyll. This established a relationship between total iron and chlorophyll. Values are shown in Table 4.

In chlorotic blades, the chlorophyll was 37.67% of the value that normal leaves have, while iron was 42.85%. There was slightly more Fe and chlorophyll in veins of chlorotic leaves.

Manganese (see Table 3) showed a more definite behavior with chlorosis. In all analyzed samples its foliar level decreased in affected leaves, both in blades and in veins. Manganese levels in sugarcane may also be affected by calcareous excess, as shown in India by Srivastava *et al* [18]. In this case, total harmful levels of $CaCO_3$ were 6.56%. There were no problems in organic soils with 2.21% $CaCO_3$.

In healthy canes, the Mn content in the leaves was higher than Fe while the opposite is true for the diseased canes.

TABLE 4. Values of chlorophyll in leaves of variety NA 56-79 compared with total Fe. La Aguadita, February 1973.

	Normal		Medium Chlorotic		Chlorotic	
Portion of the leaf	Chlorophyll mgr/gr	Fe ppm	Chlorophyll mgr/gr	Fe ppm	Chlorophyll mgr/gr	Fe ppm
Blades	2.15	56	1.83	36	0.81	24
Nervures	0.53	22	0.65	24	0.57	30

The importance of the Fe/Mn relationship is already established. In sugarcane, there is a lack of Fe when the Fe/Mn quotient is less than 1 (Samuels[16]).

To add further support in the significance of the Fe/Mn relationship, samples from La Aguadita showed the chlorotic blades gave a quotient of less than one. At Caimancito, the problem of immobility was outstanding since the relationship of Fe/Mn was superior to 1. This situation is similar to that found in India by Srivastara *et al*[18]. It might mean that we will be facing a lack of Mn which would be associated with manganese inmobility in sugarcane.

Evans[5] found Fe/Mn values of 1.35 to 1.60 in green leaves and he pointed out that a real deficiency of Fe is present when its level is less than 5 ppm in the leaf blades.

Numerous Fe/Mn relationships were calculated for normal cases of different ages in Hawaii (Humbert[9]). The study showed that between 4 and 13 months of age, the quotient varied from 1.25 to 6.50.

The K/Ca and K/Ca + Mg relationships agreed with what was found for other crops (Nijenshon[14]). Due to the larger proportion of K than Ca and Mg in chlorotic leaves, the relationships established increased in all chlorotic blades. In leaf veins and rolled spin leaves from Caimancito plantations, such values decreased. From the nutritional diagnosis point of view however, the blade contents were more interesting.

The relationship P/Fe was established and a definite trend of increase in chlorotic blades was observed. De Kock and Wallace[4] found the same trend in raspberry leaves. They noted that excessive phosphate in soils produced changes in the leaf composition, which are characteristic signs of lack of iron.

Figures 3 and 4 show the occurrence of ferric chlorosis in sugarcane field and the typical leaf symptoms.

Problems of calcareous in the presence of high water table.

Trials in Ovanta, near the San Pablo Sugar Mill area, showed completely different results. The area has humid climate, with annual rainfalls of 980-1200 mm., and is located at the outset of the physiographic area called "llanura deprimida".

The water table in the area can be usually found between 30 to 60 cm and less frequently between 60 to 90 cm. Table 6 shows the details of the quality of water found in the water table.

There is an evident predominance of calcium and magnesium bicarbonate, whose proportions regarding total addition of anions and cations were 84.22 and 76.67% respectively.

Table 7 shows the analysis of soils corresponding to those samples. They have a high total and active calcium carbonate content besides a fairly good amount of organic matter and with the interchange complex is practically saturated with calcium and magnesium.

FIGURE 3a. Affected leaf showing the typical symptoms of intervein chlorosis and necrosis of one of its borders.

FIGURE 3b. Normal leaf

FIGURE 4a. A view of the La Aguadita plot, showing marked chlorosis of cane plantation, reduced height and sparse stubbing.

FIGURE 4b. Sugarcane plantation in Tucuman affected with ferric chlorosis.

The three soil profiles analyzed were of medium texture (loam). The color of the soil layer at 30-40 cm presented a very typical grey color.

By comparing these figures with total and active $CaCO_3$ found in other places and with the linear regression given in Table 1 we may be led to conclude that sugarcane culture is not economical in these soils. This was not so, however. The yields obtained in that plot were the highest for all the cases under study (Table 5), while in other cases, the quality of sugarcane juices was affected by $CaCO_3$ (Table 5).

Stubbing of the sugarcane plantations or the whitish yellow color as symptoms of ferric chlorosis were not visible. Leaves with slight symptoms showing iron lack were scarcely found. The quality of juice was very good and no differences could be established in the samples with regards to the chlorotic and the green portions.

Normal sugarcane growth under these conditions has been governed by the following causes:

- facilitated absorption of ferrous iron due to a reduction in ferric iron under hydromorphic conditions during crop development. We detect the situation from the characteristic grey color of soils
- high levels of organic matter in the soil layer
- sugarcane growth under water balance which can be described as permanent potential evapotranspiration

TABLE 5. Average values in juice quality of sugarcane planted in soils with calcareous problems. Height and weight of millable stalks

Site of Analysis	Brix %	Pol %	Purity %	Pol % Cane	Factory rende-ment	Reducer Sugars	Millable Stalks			
							Height	m	Weight / Stalk (Kg)	
La Aguadita (Tucuman) NA 56-79										
Normal canes*	18.07	15.91	88.04	12.88	9.74	0.355	2.257	100	1.805	100
Chlorotic canes* (15-6-73)	15.97	13.44	83.96	10.88	8.04	0.392	0.837	37.08	0.340	18.83
Delfin Gallo (Tucuman)*** NA 56-30										
Normal canes	12.35	8.14	59.87	6.59	4.13	–	1.540	100	0.956	100
Chlorotic canes (15-4-77)	10.60	5.80	44.33	4.70	2.02	–	0.920	59.74	0.430	44.97
Caimancito (Jujuy) NA 56-83										
Normal canes	18.62	16.38	89.93	13.26	10.82	–	1.715	100	1.266	100
Chlorotic canes (21-5-76)	18.47	15.88	85.89	12.86	10.38	–	1.344	78.36	0.649	51.26
El Naranjo (Tucuman)*** NA 56-79										
Normal canes	16.36	12.52	76.52	10.14	7.69	–	1.674	100	0.892	100
Chlorotic canes (13-4-76)	13.26	8.75	65.98	7.09	4.87	–	0.822	49.10	0.422	47.30
San Pablo Sugar Fact. NA 56-79							**	**		
High calcareous soils showing hydromorphy (7-9-73)	19.60	17.72	90.55	14.38	11.89	0.328	2.742 (2.50-2.98)		1.884 (1,510-2,390)	

* *Average diameter: Normal = 3.3 cm (100%) and chlorotic = 2.3 cm (69.7%)*
** *These values plus number of stalks per hectare meant a rendement of 101.74 t/cane/ha*
** *Analysis performed during maturity period; therefore the low sucrose values.*

– lack of clay horizon up to 90 cm

– quality of non sodic water table (C_3S_1)

Let us analyze the first case. It is knwon that ferrous ion is the most soluble element for plants. This situation occurs in certain flooding conditions since under normal aeration soil conditions, Fe prevails as ferric ion.

Black[3] states that grey color in soils is associated with ferrous iron reduction in soils with low reduction-oxidation potential.

The presence of a high water table makes it difficult for O_2 to spread normally in the soil, favoring Fe and Mn reduction to their divalent forms. Merkle[11] points out that these reduced elements are especially found in water saturated soils, but they can readily be oxidized if aeration conditions of soil are changed.

The data of exchangeable iron (Fe^{++} up to the water table are included in Table 8. These values were increased to over 100% upon contact with water but were not reached under conditions when water was lacking.

As regards to the REDOX potential of the soil under study, there was a remarkable decrease in the presence of the water table.

Black, referring Aomine[3] in 1962, said that the characteristic red and brown color of iron-ferric soils is found where the REDOX potential is over the 300mV. In our case (pit No. 3), ferric patched from 20 cm deep was found. Yamazaki (referred to by Black) found an oxidation-reduction potential of 400 mV in ferric spotted soils.

Shishov *et al*[17] in 1973 found that in humid carbonated soils with moisture near the field capacity, the REDOX potential was from 485 to 570 mV decreasing to 122-152 mV under excessive moisture in soil and anaerobic conditions with a complete absence of the sugarcane germination. A critical limit of 200 mV of REDOX potential for the germination of sugarcane was then fixed.

The high organic matter content in these soils with the water table near the surface may have contributed to the iron reduction.

Tisdale and Nelson[19] observed that the organic matter participates actively in the ferric reduction. Fe^{++} values were greater as the addition of organic matter increased. They mentioned that in wet soils, it is reduced to the ferric state, which was accelerated due to the presence of high levels of organic matter in the soil. Probably, this is the situation found in Tucuman.

CONCLUSIONS

A study has been carried out in different areas of Tucuman and Jujuy in order to lay out tentative critical levels of sugarcane tolerance to calcareous of soil expressed as total and active calcium carbonate, respectively.

TABLE 6. Quality of water table at San Pablo Sugar mill area. September, 1976.

	Saline Residue	CE 10^6	pH	Anions ml/l $CO_3^=$	CO_3H^-	CL^-	$SO_4^=$	Addition
Analytical Data	695	1,080	7.80	0	8.97	1.40	0.28	10.65
%.,	—	—	—	—	84.22	13.14	2.63	100.00

	Saline Residue	CE 10^6	pH	Cations ml/l Ca+Mg	K^+	Na^+	Add.	RAS	CO_3Na Res
Analytical Data	695	1,080	7.80	7.74	2.61	0.30	10.65	1.40	1.23
%.,	—	—	—	72.67	24.50	2.82	100.00	—	—

TABLE 7. Analysis of soils corresponding to average values of 12 trial pits in Ovanta (San Pablo sugarcane factory). Calcareous soils planted with sugarcane showing hydromorphy problems. Variety NA 56-79.

Analysis	0-30 cm	30-60 cm	60-90 cm
Clay %	21.19	15.70	11.91
Silt %	48.18	40.12	41.95
Sand %	30.62	43.39	46.13
pH (paste)	8.00	7.90	7.80
Organic Matter %	4.67	3.04	2.57
Exchange cations: Ca + Mg ml/100 gr	32.92	31.78	33.15
K ml/100 gr	0.75	0.82	0.97
Na ml/100 gr	1.23	1.20	1.17
Total $CaCO_3$ %	10.01 (4.90 - 16.24)	3.90 (0.70 - 7.14)	0.98 (0.66 - 1.20)
Active $CaCO_3$ %	4.81 (3.20 - 8.40)	2.08 (0.48 - 4.32)	0.64 (0.48 - 0.80)

Note: Normal depth of water table between 30 and 60 cm; in many occasions between 60 and 90 cm.

Marked predominance of grey soils starting from 30 cm in the presence of water.

TABLE 8. Values of exchangeable Fe^{++} in soil and of oxido-reduction potential (E) in ppm of dry soil and milli-volts respectively. San Pablo Sugar Mill Tacuman.

Profile	Depth	E	Ferrous iron	
		mV	Fe^{++}(ppm)	%
	0.25	342	19.12	100.00
Pit No. 1	25-50	312	32.57	170.34
	50-80*	132	39.63	207.26
	0-20	347	24.63	100.00
Pit No. 2	20-55	367	33.31	135.24
	55-80	247	71.49	290.25
	0-20	372	17.21	100.00
Pit No. 3	20-40	377	21.55	125.22
	40-60	392	23.44	136.19
	60-90	397	31.80	184.77
Water Table				

At the surface (superficial horizon) (0 to 30 cm) of the soil it was found that an average value or 1.50 to 2% total $CaCO_3$ causes the crop to show symptoms of chlorosis. The situation became more severe with values higher than 3%. For active $CaCO_3$, the figures are lower with 1 to 1.50 and higher than 1.50 to 2% respectively.

These situations are associated with pH 8 before the total absence of soluble and/or interchangeable salts and low organic matter content.

By means of linear equation it was found that 2% total $CaCO_3$ will reduce the sugar plantation height to 23%, and a 4% total $CaCO_3$ will cause a 50% reduction.

Calcareous excess severely reduced the content of chlorophyll in sugarcane leaves. Values of chlorophyll higher than 2 mgr/gr of fresh matter can ensure a normal photosynthesis and satisfactory sucrose levels on the juice.

By using the linear equation, it was found that values of 5% of total $CaCO_3$ and active $CaCO_3$ of 1.76% reduced chlorophyll in the leaf to almost zero making an accurate physiological activity impossible.

The negative association turned out to be closer between active $CaCO_3$ and the chlorophyll content in leaves.

There were obvious alterations in the nutritional balance of sugarcane

grown in soils with excessive calcareous.

Foliar analysis showed that nitrogen, calcium and manganese decreased in blades of chlorotic plants. Iron had smaller values in portions with chlorosis when a deficiency was involved. On the contrary, ion content was increased when its immobility was the problem.

Phosphorus, potassium and magnesium showed a definite trend of increase in chlorotic canes.

The value of the Fe/Mn quotient varied depending on whether iron deficiency or immobility was prevalent. In the first case, its value was lower than the unit which was higher than the second one. The quality of juice was always lower in chlorotic plants as a result of diminishing chlorophyll content. The relationships K/Ca and KCa + Mg as well as the Fe/F quotient always increased in chlorotic canes. Those associations contributed to confirm the detected problem which was ferric chlorosis due to excessive calcareous in soil.

We must bear in mind that calcium carbonate level in the soil of those areas were controlled with foliar analysis to guide fertilization practices.

A different situation was found if $CaCO_3$ had a close non-saline water table near the surface. Under these conditions, the lack of adequate aeration favors the reduction process of the ferric ion in the soil, helping sugarcane absorption. Since ferrous iron is more soluble, the indirect negative effect of calcium disappears and neither the typical symptoms of intervein chlorosis nor decrease in production were observed.

This situation was detected with average values of 10% for total $CaCO_3$ and 4.80% for active $CaCO_3$.

Under the above conditions, there would be prevalence of grey soils down to 30 cm deep.

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CLOROSIS DE HIERRO DE CAÑA DE AZUCAR EN SUELOS EXCESIVAMENTE CALCAREOS

Franco A. Fogliata y Vicente N. Bustos

RESUMEN

Se ha efectuado un estudio tendiente a precisar la influencia del $CaCO_3$ total y activo del suelo sobre el crecimiento y producción de la caña de azucar y tambien sobre la concentracion de nutrientes en las hojas.

Los resultados señalan que el efecto del $CaCO_3$ fue variable según los niveles de materia orgánica en el suelo y la presencia o no de napa de agua cercana a la superficie.

Estas condiciónes influyen en el grado de solubilidad del hierro ferroso intercambiable, pudiendose reducir la influencia de los altos niveles de $CaCO_3$.

Con bajos niveles de materia orgánica y sin la presencia de napa de agua, los niveles criticos de $CaCO_3$ total en suelo fueron entre 1.50 a 2%, siendo muy severos los daños por arriba del 3%.

Expresado como $CaCO_3$ activo, esos niveles fueron desde 1 á 1.50%, siendo severos por arriba de 1.50%.

Con altos niveles de materia organica y presencia de napa de agua, el cultivo de la caña de azucar tolero bien valores promedios de 10% de $CaCO_3$ total y 4.80% de $CaCO_3$ activo.

El potencial REDOX del suelo disminuyó en presencia de la napa de agua y se incrementó el valor de hierro ferroso intercambiable.

Hubo evidentes alteraciones en la concentración de nutrientes en las hojas como consecuencia del $CaCO_3$, unido a una acentuada clorosis a medida que aumentaba el $CaCO_3$ en el suelo.

Esta situación no se dió en suelos con alto contenido de materia organica y presencia de napa de agua.

MOISTURE-RETENTION CURVES OF THE SUGARCANE CULTIVATED SOILS IN PERU

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ABSTRACT

The soil moisture-retention curves were determined for the Peruvian cane-growing area with a sampling density of one point per 1,600 ha. Samples were obtained from every 30 cm down to the depth of 90 cm.

The obtained mathemetical model expressed the water potential in the soil as a function of its moisture content and the saturation percentage (Arany number, K_A). The saturation % is a commonly used characteristic in the Peruvian cane sugar industry and can be determined easily. The regression analysis showed a correlation coefficient (R^2) of 0.76.

INTRODUCTION

Because of water deficit in the coastal valleys of Peru where the cane-growing areas are situated, it is imperative to maximize the use of the existing water resources. To attain this objective, a technical tool was designed to serve as a decision element for those in charge of irrigation scheduling. This tool is used by the "Moisture Control Service" (Eppink[2]) and is based on the moisture-retention curves or moisture characteristic curve which express the relation between content and the water potential of the soil. The soil-water potential also expressed as soil-water tensions, indicates the degree of water availability to the plant (Forsythe[4]). The moisture characteristic curves as functions of the physio-chemical properties of soils were described by different researchers, such as Wilcox[12] which established correlations between the field capacity (−0.33) and the wilting point (−15.0) with percentages of sand, clay, colloids, moisture equivalent and settling volume as the best. The relation is as follows:

$$\theta_{15.0} = 0.92 + 0.317 \ _{eq}\pm 18.5$$

where: θ_{eq} is the moisture equivalent

Petersen *et al*[8] studied the influence and bulk density of the different contents of sand, silt and clay in the retaining capacity of soils. For $\theta_{0.33}$, a closer correlation with the bulk density was found. Likewise, a closer correlation with the percentage of clay was found for $\theta_{15.0}$. The available water shows a negative correlation with both sand and clay, but a positive one with silt.

The relation of percentages of fine sand, silt, clay, organic matter and calcium carbonate to the bulk density, field capacity, wilting point and available water were studied by Shaykewich and Zwarich[10] found that the predicting equations of the bulk density, field capacity and wilting point were reliable.

Salter and Williams[9], Zawadzki[14] and Maclean and Yager[6], studied the relations between the percentage of clay and moisture of 2 pF and 4.2 pF. Osty[7] obtained a regression equation to estimate the moisture content at 3 pF with a determination coefficient of 0.95 based on the percentage of clay, fine silt, coarse silt, fine sand and coarse sand. With a determination coefficient of 0.73 it can be estimated from the percentage of clay and organic matter only.

Correlations between the moisture content at different tensions and the texture of soils of the Chicama Valley, were made by Husz[5]. Chanduvi[1] found a relation between the moisture content and its corresponding water potential at 12 atmospheres as a function of the percentage of clay.

The objective of the present work is to find a mathematical model that may relate the soil water potential with the Arany number (K_A) and the soil moisture content which are characteristics easily determined.

MATERIALS AND METHODS

The study was performed on fields of the twelve Agrarian Cooperatives of Production that are associated with the Central de Cooperativas Agrarias de Produccion Azucarera del Peru (CECOAAP) which comprises approximately 80,000 ha. The sampling density used was at the rate of one point (pit) per 1,600 ha at three depths (0-30, 30-60 and 60-90 cm).

The selection of fields in each Cooperative was carried out with the collaboration of the Field Superintendent who with their experience helped to locate sampling points where soils of different textures can be found.

Undisturbed samples were obtained for determining both bulk density and retention curves, whereas disturbed samples were obtained to determine the Arany number.

The determination of moisture contents at tensions of 0.1, 0.8, 2.0, 5.5 and 15.0 bars were made with four replications by means of the pressure ceramic plates. The determination of the Arany number was made according to the method proposed by the ICIA, Eppink[2].

Based on the results obtained in the laboratory, the water potential (Y), as a function of moisture content in vol. % (0) and the Arany number (x) can be expressed in the following mathematical model:

$$y = \frac{7\left[1 - \left(\frac{\theta}{\mu}\right)^{b}\right]^{c}}{1 + \left(\frac{t\ \theta}{\mu}\right)v}$$

where: μ = soil porosity

b and c = constants

Constants b and c are then calculated obtaining 3.6 and 2.4, respectively. Finally, the mathemtical relation of t, μ and v was determined.

RESULTS AND DISCUSSION

As a result of the laboratory analysis, it was found that the Arany number of the samples was between 23 and 130. This corresponds to textures which range from sandy to clay according to the USDA. The bulk density varied between 1.10 and 1.70 g/cm^3. It was also observed to slightly vary with depth. This was in accordance with a report by Vasquez *et al*[12]. The salanity level of samples was low, with a maximum value of 1,000 mmhos cm of electrical conductivity in the extract, which resulted from the exclusion of this variable in the final model. Likewise, both organic matter and calcium carbonate contents were low.

The results of the regression analysis as shown in the general model are as follows:

$$\mu_i = 100 - 37.735848\left[1.2916 + 0.2442\ e^{\frac{-(X-23)^2}{a_i}}\right]$$

$$V = 0.78 + 0.4075\ \left(\frac{X-23}{13.375}\right)^2\ e^{-\frac{(X-23)^2}{13.375}}$$

$$t = 0.60 + 11.70\ e^{-}\ [(X-23)\ /\ (10.3 - (X-23)\ /\ (10.7)]^{0.5}$$

where: i = 1,2,3, indicators of depths 0-30, 30-60, and 60-90 cm, respectively

9_1 = 23.8162)

9_2 = 24.1139) magnitude of constants

9_3 = 24.9731)

e = base of natural logarithm

x = saturation percentage

Since the final model is only a function of X its application is reliable if it has high correlation ($R^2 = 0.76$).

Figure 1 shows the retention curves generated according to the model based on the first depths where observations on the quantity of available moisture on the different types of soil, conforms with that of Stakman and Harst[11], Husz[5], and Eppink[2].

Though it was true that water retention phenomenon plays a very important role, the porosity has an indirect relation to the saturation percentage (Vasquez

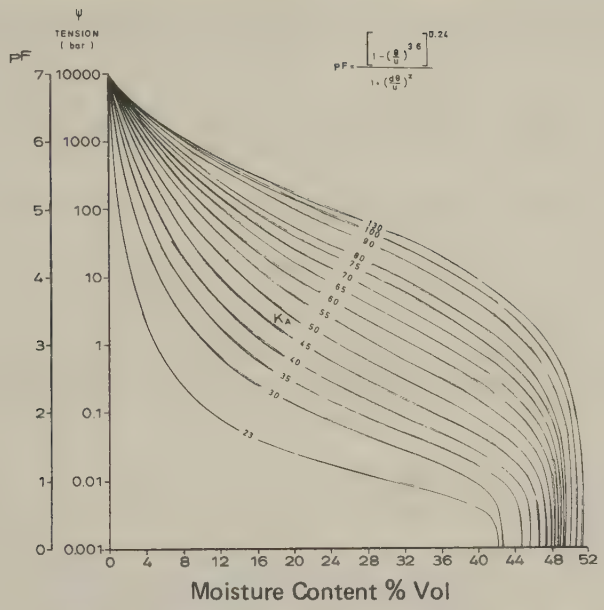

FIGURE 1. Moisture retention curves for different soil textures.

et al[12]. Moreover, it was intended that the results be obtained from easy routine determination so that they may have practical application.

CONCLUSIONS

The general model found in this work gives grounds for confidence at $R^2 = 0.76$. Besides it is very practical since it is a function of only one soil physical characteristic (K_a) the determination of which is only routine.

It is possible to determine the soil moisture-retention curve by means of a mathematical model derived from the function of the saturation percentage or the Arany number (K_A) which is the best index of soil texture.

The textural range under study included all the soils of the Peruvian cane-growing area.

The soil's organic matter content, electrical conductivity and calcium carbonates were low.

The bulk density of studied soil varied between 1.10 and 1.70 g/cm^3.

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CURVAS DE RETENCIÓN DE HUMEDAD DE SUELOS CULTIVADOS CON CAÑA DE AZÚCAR EN EL PERÚ

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RESUMEN

Las curvas de retención de humedad en el suélo, fuéron determinadas para el area cañera del Perú, con una densidad de muestreo de un punto cada 1,600 ha, obteniendose muestras cada 30 cm hasta, la profundidad de 90 cm.

El modelo matemático obtenido expresa el estado energético del agua en el suelo, en funcioń de su contenido de humedad y el porcentaje de saturación (Cifra Arany, K_A); por ser esta ultima una caracteristica muy usada en la industria azucarera peruana y de facil determinación rutinaria. El analisis de regresión arrojo un coeficiente de determinación (R^2) de 0.76.

THE VALUE OF SUGARCANE FROM THE TOTAL ENERGY STANDPOINT

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ABSTRACT

The related values of processing the whole cane plant rather than only the millable stalk indicate that the whole plant has economical potential from the energy standpoint. Although the yield of crystallized sugar is reduced slightly, utilization of the tops could result in an increase in alcohol production of 5 to 6% from the total sugar increase. The greater amount of fiber if converted into power would yield 500-600 kwhr/ha of additional electrical energy.

Whole cane processing however, requires more milling capacity and gives juices with more color and ash, and with greater lime consumption clarification.

INTRODUCTION

The effect of cane topping has been extensively studied because of its influence on the quality of cane for sugar production.

Several papers on the subject have been published by Cobeman[3], Oliveira[6], Stewart[8] and Wood[10], showing the adverse effect of tops on cane processing.

The sugar recovery and the economics of milling untopped cane was studied by Payne and Birkett[1]. They found little influence of tops on recovery and indicated the value of processing untopped cane.

Sugarcane has the highest annual photosynthetic potential of any crop the total energy available can be used by utilizing all the fiber as well as total sugars present in the whole plant.

Excess fiber from the tops can be burned for fuel for the production of electrical energy while the total sugars in the tops can be fermented to give fuel alcohol.

This paper gathers information on the composition of untopped cane, along with composition of tops and estimates the economic value of the whole cane plant.

MATERIALS AND METHODS

Representative samples of cane of 20 stalks each were collected from commercial fields at the Bom Retiro factory before and after burning. In the laboratory the tops were removed at the break point. Four samples resulted – burned and unburned cane with and without tops.

The cane and the tops were analyzed for fiber refractometer solids, pol, reducing sugars, pH, conductimetric ash, P_2O_5, total hardness (Ca + Mg) and attenuation index at 420 nm. The hydraulic press method was followed[9].

Clarification tests were made by defecation (liming to pH 7,0) and sulfo-defecation (sulfitation to pH 4.0 – liming to pH 7.0) and the juices are analyzed for refractometer solids, pH, conductimetric ash, and attenuation index at 420 nm. The mud volume after 60 minutes was also measured.

The data were subjected to statistical analysis of variance by the F-test using a randomized block design with 2 treatments and 12 replications.

RESULTS AND DISCUSSION

The overall average of the analysis of the cane and tops and the statistical results are shown in Tables 1 and 2.

Cane and juice quality

It can be seen in Table 1 that refractometer solids, pol, and pH of the juice and refractometer solids, pol purity and extracted press juice % cane were higher in cane without tops than in cane with tops. On the other hand, the figures corresponding to reducing sugars, ash, CaO, and P_2O_5 of the juice and fiber % cane were higher in cane with tops. From the point of view of sugar production and quality, the cane with tops has some negative effects. For example, fiber % cane was higher at 16.2% and 11.4% in burned and unburned cane with tops respectively. This fiber can decrease the crushing rate, but will also increase the amount of bagasse to the boilers. The color of the juice increased 45.6% and 52.1% in cane with tops, resulting probably in a higher sugar color. Clarification should be improved with the higher content of P_2O_5 in cane with tops, respectively 19.8% and 16.5%.

Tops quality

In Table 2, the general average for the analysis of tops for both treatments are given. The figures show that the tops had a low pol content and high value for reducing sugars, ash, CaO, P_2O_5 and color in the juice. The percentage of tops in relation to cane without tops was 14.7% and 16.3% for the burned and unburned cane respectively. This is due to the green leaves surrounding the tops in the unburned cane and the loss of moisture in the burned cane.

Clarification by defecation

In Table 3 are shown the average results for the defecation tests performed in cane with tops and without tops. In both treatments, the F-test and the statistical mean difference between the averages, were significant. It is clear that the cane with tops produced a clarified juice with lower quality than cane without tops. The main parameters to judge the quality of the clarified juice were ash and color. The percentage variation for color was 32.9% and 43.0%. Ash % refractometer solids was 26.5 and 32.1% between cane without and with tops for burned and unburned cane respectively.

TABLE 1. Average values for burned and unburned cane with and without tops

Elements	Average				Burned		Unburned	
	Burned		Unburned		F test	LSD (5%)	F test	LSD (5%)
	W. Cane	Top Cane	W. Cane	Top Cane				
Brix	18.4	19.4	18.8	19.9	46.7**	0.28**	27.8**	0.44
Pol	16.0	17.3	16.5	17.1	47.0**	0.41	41.1**	0.57
Reducing sugars	0.63	0.51	0.64	0.52	19.3**	0.06	7.6*	0.10
pH	5.21	5.29	5.24	5.31	21.9**	0.04	25.8**	0.03
Ash	0.74	0.69	0.68	0.53	94.6**	0.04	94.4**	0.04
mg CaO/1	1099	965	1069	927	17.6**	70	30.6**	57
mg P_2O_5/1	297	248	296	254	24.9**	22	54.8**	13
a*420 x 10	262	180	292	192	94.7**	18	128.1**	20
Refr. solids % cane	16.0	17.1	16.4	17.6	45.5**	0.4	41.5**	0.4
Pol % cane	13.9	15.4	14.4	16.0	64.4**	0.4	48.7**	0.5
Purity	86.8	89.5	87.3	90.9	24.0**	1.2	33.3**	1.4
Fiber % cane	12.9	11.1	12.7	11.4	19.3**	0.9	39.1**	0.5
Ext. juice % cane	63.9	68.1	62.7	68.1	148.2**	0.8	187.8**	0.9

** = *significant at 1% level*
* = *significant at 5% level*

The consumption of milk of lime at 2.0 Be was 1.21 and 1.37 times more for cane with tops. This may increase the scaling in the evaporators and decrease the evaporation rate. The cane with tops produced more mud after 60 minutes.

Consequently more are of subsiders and filters will be necessary to obtain a good clarification.

Clarification by sulfo-defecation

The average figures and the statistical results for sulfo-defecation process are given in Table 4. The sulfo-defecation process was more effective in removing color but it producted more ash in the clarified juice than the defecation process. For color and ash figures, the percentual variations were 20.0 – 38.8% and 27.0%

TABLE 2. Average values for analysis of tops

Elements	Unburned	Burned
Refr. Solids	10.6	10.8
Pol	5.2	5.6
Reducing sugars	1.35	1.24
pH	5.15	5.13
Ash	1.72	1.79
Ash % Refr. Solids	16.67	16.76
mg CaO/1	1940	1880
mg P_2O_5/1	540	585
a* 420 x 10	1429	1244
Refr. Solids % Tops	8.5	8.6
Pol % Tops	4.7	4.5
Purity	55.3	52.3
Fiber % Tops	19.7	19.8
Extracted press juice % Tops	40.1	44.6
Tops % topped cane	16.3	14.8

TABLE 3. Average values for clarification tests by defecation with topped and untopped cane

Elements	Average				Burned		Unburned	
	Burned		Unburned		F-test	LSD	F-test	LSD
	W. Cane	Top. Cane	W. Cane	Top. Cane				
Purity	88.1	90.2	88.3	91.2	48.3**	0.7	49.9**	1.00
Ash % Brix	4.3	3.4	3.7	2.8	352.7**	0.1	71.5**	0.2
a* 420 x 10	202	152	206	144	60.0**	15.0	160.4**	11.0
pH	5.97	6.03	5.99	6.07	5.1*	0.06	16.5**	0.04
Milk of lime 2^o Be (ml/l)	13.3	11.0	12.7	10.0	19.7**	0.4	28.2**	0.5
% mud 60 Mn	9.5	8.0	9.4	8.8	11.9**	1.0	1.3	1.2

** = *significant at 1% level*

* = *significant at 5% level*

— 32.2 % more for cane with tops in burned and unburned cane respectively.

The milk of lime consumption increased 32.4 % and 31.2 % when the cane with tops was processed. The percentage of mud was 1.17 and 1.13 times higher in cane with tops.

Theoretical Recovery Calculations

The data obtained for the analysis of the cane and tops by the press methods were used to calculate the recoverable sugar, and recoverable alcohol per ton of cane and per hectare by empirical formula Murata and Gibson[5]. The energy production obtained by the excess of bagasse was calculated for a mill thermally balanced with the cane without tops and with a crushing rate of 300 TPH. The results are shown in Table 5 for burned and unburned cane.

Recoverable sugar

The formula used to calculate the recoverable sugar is:

$$\text{Recoverable Sugar} = (10\,S - 0.76\,F - 6.9)\left(\frac{5p - 200}{3\,P}\right)$$

where:

S = pol % cane
F = fiber % cane
P = purity % cane

The milling of cane with tops decreased the recoverable sugar per ton of cane by the amount of 15.6% and 17.2% in relation to cane without tops. Because of the higher tonnage of untopped cane, the production per hectare decreased only by 0.5% and 0.1%.

Alcohol production

The probable alcohol production decreased by 9.3% and 9.6 % per ton of cane when the cane with tops was milled, but without taking in account the losses in processing. On the other hand, the production per hectare increased by 5.1% to 6.1% respectively in burned and unburned cane with tops. This would be sufficient to justify the use of cane with tops as raw material for the alcohol process.

The empirical formula used to calculate alcohol production was

$A = 4.33\,TS$, where A is the produced alcohol and TS is the total sugar % cane.

Electrical energy production

The milling of cane with tops will increase the amount of fiber in cane and consequently of bagasse produced after milling. The surplus of bagasse can be used

TABLE 4. Average values for clarification tests by sulfo defecation in burned and unburned cane

Elements	Average				Burned		Unburned	
	Burned		Unburned		F-test	LSD	F-test	LSD
	W. Cane	Top. Cane	W. Cane	Top. Cane		(5%)		(5%)
Purity	87.8	90.3	88.7	91.1	61.7**	0.7	17.6**	1.3
Ash % Brix	4.7	3.7	4.1	3.1	222.8**	0.2	77.8**	0.3
a* 420 x 10	138	115	143	103	31.4**	9.4	55.8**	12.5
pH	6.36	6.35	6.39	6.45	0.3	0.05	9.1**	0.04
Milk of lime	13.5	10.2	12.6	9.6	68.5**	0.9	13.3**	1.9
% mud 60 Mn	13.4	11.13	13.2	11.7	5.9*	1.9	4.7	1.6

** = *significant at 1% level*
* = *significant at 5% level*

TABLE 5. Recoverable sugar and alcohol, and electrical energy produced by topped and untopped cane per ton cane and per hectare (Theoretical calculation)

Elements		Burned			Unburned		
		W. Cane	Top. Cane	%	W. Cane	Top. Cane	%
Recoverable	kg/TC	110.6	127.8	−15.6	115.4	135.2	−17.2
Sugar	t/ha	10.16	10.21	− 0.5	10.74	10.81	− 0.7
Alcohol	1/TC	65.9	72.0	− 9.3	68.5	75.1	− 9.6
	1/ha	6052	5760	+ 5.1	6373	6008	+ 6.1
Additional							
Electrical	kwhr/TC	5.8	—	—	6.5	—	—
energy	kwhr/ha	538.1	—	—	604.7	—	—

to produce steam and electrical energy further than that necessary to maintain the thermal balance in the factory. The excess of bagasse was sufficient to produce 5.9 and 6.5 more kwhr per ton of cane with tops for burned and unburned cane respectively or 538.1 and 604.7 kwhr/ha. Therefore a factory with a milling rate of 300 TPH can produce more 1770 and 1950 kwhr per day for burned and unburned cane with tops respectively.

Economics

From the point of view of economy in the sugar mill the processing of cane with tops for burned cane would have an additional cost of around US$5.07 per ton of cane for sugar production. If the economic balance is calculated as a function of the area, the cane with tops would also provide a negative balance of US$

25.15 per hectare without considering the cost of processing and some influence on sugar quality and the reduction cost for the manual cutting. For unburned cane the additional cost would be US$ 5.65 per ton of cane, a negative balance of US$ 18.05 per hectare.

The alcohol produced per ton of cane with tops would have an additional cost of US$3.35 but an extra earning per hectare of US$79.53 and US$101.56 for burned cane and unburned cane respectively. Not included in the calculation was the cost of processing in relation to cane without tops. The increased yield of alcohol results in an overall return of $54.38 per hectare for burned cane and $83.51 for unburned cane.

CONCLUSIONS

The results of this study made clear that the quality of cane with tops is lower than that of cane without tops. In sugar production it modifies some parameters like color and ash that can contribute to a low quality of sugar. The color and ash of the clarified juice from cane with tops is higher than that of cane without tops for both defecation and sulfo defecation processes. The crushing of cane with tops will produce less recoverable sugar and alcohol per ton of cane, practically the same production of sugar per hectare, but it will increase the alcohol production per hectare. With excess bagasse it will be possible to generate additional quantity of electrical energy. There will be an extra cost to produce sugar and alcohol per ton of cane with tops, but the alcohol production will give a better profit per hectare, without including the process costs.

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EFECTOS DE DESMOCHAR SOBRE CALIDAD DE LA CAÑA DE AZUCAR EN CONJUNTO A LA PRODUCCION DE AZUCAR, ALCOHOL Y ENERGIA

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RESUMEN

Los valores relativos del procedimiento que usa toda la planta de la caña de azucar en vez de solo el tronco molible indica que la planta entera tiene potencial economico desde el punto de vista de energia. Aunque el rendimiento de azucar cristalizado es un poco reducido, la utilizacion de las puntas pueden resultar en un aumento en la produccion de alcohol de 5 al 6% del total del aumento de azucar. La aumentada cantidad de fibra, si se convierte en energia, podria resultar en 500 a 600 kwhr/ha de energia electrica adicional.

El procedimiento que usa la caña entera requiere mas capacidad de molienda y rinde jugos de mejor color y con mas ceniza, y con mas consumo de cal en su clarificacion.

EFFECT OF CANE LODGING AND RAT DAMAGE ON CANE QUALITY AND DETERIORATION AFTER HARVEST

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ABSTRACT

Lodging markedly lowered cane juice quality, but rat damage resulted in the most drastic decrease in juice quality. The theoretical sugar yield of the lodged cane was reduced by 17.2% compared to 56.4% with lodged rat-damage cane. Lodged and lodged rat-damaged cane deteriorated at the same rate with elapse of time after cutting.

INTRODUCTION

Cane lodging usually occurs in the high tonnage producing areas under the conditions of free irrigation and narrow spacing. As high as 25% of the area planted to cane may tend to lodge. The lodged cane is usually subjected to rat damage resulting to losses in both cane weight and sugar content.

Published information about sucrose losses in cane due to lodging are meager. Nelson *et al*[3] reported that lodging of sugarcane might be a serious problem considering that the method of determining cane susceptibility to that source of loss is difficult. In studying the lodged cane problem in Australia, Scotney[7] suggested that the low sugar content of lodged cane could be due to lack of exposure to sunshine during the earlier months of the year, and concluded that selection of lodging resistant varieties was the only solution to the problem.

Lodging of cane usually increases the problem of rat damage. Lindsey[1] in Hawaii reported that rat damages sugar cane by eating a portion of stalk internodes, usually in the zone between the ground and the top of the mat formed by the lodged cane. Stalks damaged by rats are not usually completely cut and have a portion of the rind still intact. Such injuries may either kill the stalk or severely reduce sugar content due to souring organisms which enter the injured cane. In the Philippines, Porquez and Ledesma[4] reported that the degree of stalk rat-damage varied from 11.08% to 24.27% with an average of 15.30%, while the accompanying sugar losses ranged between 2.20% and 9.62% with a mean of 5.08%. The same authors estimated the sugar loss per hectare by 0.133 to 0.857 ton. Teshima[8] estimated the amount of rat-damaged cane and the corresponding sugar loss in Hawaii by 19.24% and 3.58% respectively.

Thus study was carried out to investigate lodging of sugarcane and

damage of lodged stalks by rats as a possible cause of sucrose losses.

MATERIALS AND METHODS

Erect and lodge cane plots of the first ratoon crop of variety NCo 310 grown under similar conditions were compared. The effect of damaging lodged cane by rats was also studied. The selected samples were lodged in August and were tested during the next December and January and then at ten-days intervals until March. At each date of analysis two samples of 25 stalks each were secured for each treatment and prepared for analysis according to the procedure described by Sayed[6]. Sampling for the deterioration study of both erect and lodged cane was also patterned after Sayed .

The primary juice of the cane samples was extracted by an electric pilot mill (Sabri[5]), screened and mixed thoroughly. One-liter sample of the juice was taken in glass cylinder for juice analysis.

Juice analysis

After 15-20 minutes settling time the juice samples were analyzed for gravity brix, apparent sucrose and reducing sugars. Then the juice and cane quality parameters, apparent purity, glucose ratio, apparent sucrose percent cane and theoretical sugar yield were calculated by the method described by Meade[2].

RESULTS AND DISCUSSION

Figure 1 shows the apparent brix, sucrose, purity and glucose ratio of the erect, lodged and lodged-rat damaged canes as a mean of 14 observations taken at intervals throughout the maturity phase and the first part of the milling season from the end of December till the middle of March. The erect cane exhibited the highest brix, sucrose, purity and lowest glucose, ratio followed by the lodged cane, while the lodged rat-damage cane showed the most drastic decrease in brix, sucrose, purity and the highest increase in glucose ratio.

These data indicate that cane lodging resulted in 2.79, 3.04 and 2.8 degrees in brix, sucrose and purity respectively, while glucose ratio increased by 0.4 degree. In the lodged rat-damaged cane these unfavorable changes amounted to 8.18, 9.77 and 18.6 degree drop in brix, sucrose and purity respectively while the glucose ratio increased by 9.4 points. The lower quality of the lodge cane may be attributed to lack of exposure to sunshine during the earlier stages of maturity phase as suggested by Scotney[7], which might result in lower rate of photosynthesis. Moreover, the rat injuries may either kill the stalk or severely reduce sugar content due to souring organisms which enter the injured cane as reported by Lindsey[1]. This reasons added to the above mentioned effect on cane lodging itself may stand for the inferior quality recorded for the lodged rat-damaged cane.

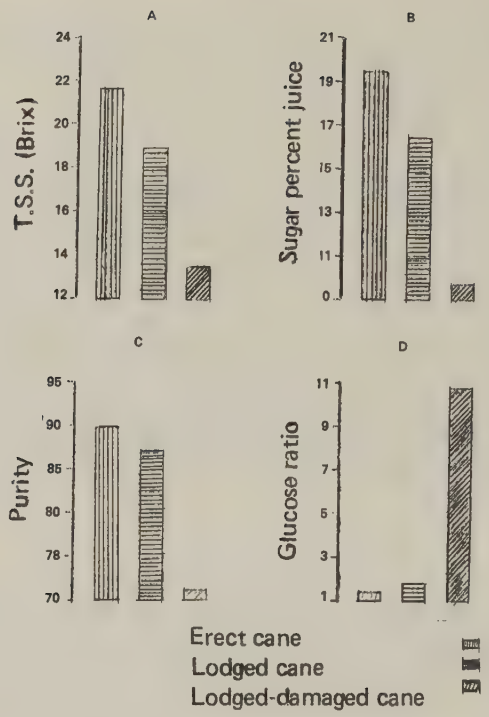

FIGURE 1. Juice quality of erect, lodged and lodged rat-damage cane.

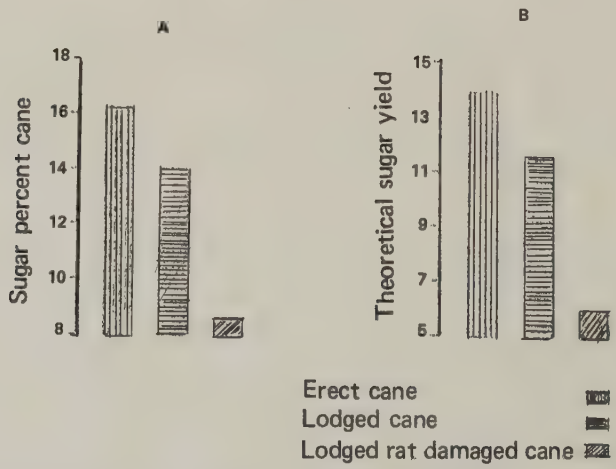

FIGURE 2. Average sugar percent cane and theoretical sugar yield in erect lodged rat-damaged cane

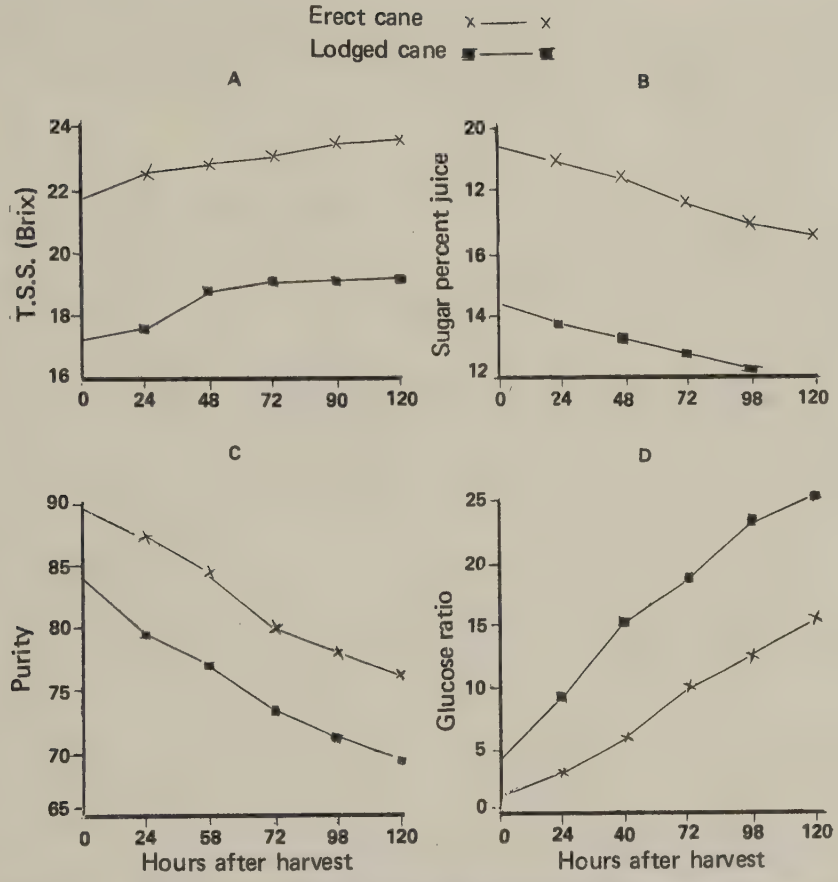

FIGURE 3. Changes in juice quality parameters with elapse of the time after harvest.

Data in Fig. 2 show the effects of lodging and rat damage of cane on sugar percent cane and theoretical sugar yield. It can be seen that cane lodging only resulted in a loss of 2.17 and 2.38 points in sugar percent cane and theoretical sugar yield respectively, while in the lodged rat-damaged-cane these losses amounted to 7.61 and 7.81. It could be stated that the percent loss in the theoretical sugar yield was 17.2 in the lodged cane compared to 56.4 in the lodged highly rat damage cane.

Porquez and Ledesma[4] reported an average loss of 5.08 % of sugar per hectare when the average of stalk rate damage was 15.30%, where as Teshima[8] estimated the amount of rat-damage cane and the corresponding sugar loss at 19.24% and 3.58% respectively.

Figures 3 and 4 compare the changes in the juice and cane quality parameters in both kinds of cane with elapse of time after harvest up to five days. It is quite clear that the rate of deterioration as indicated by the changes in

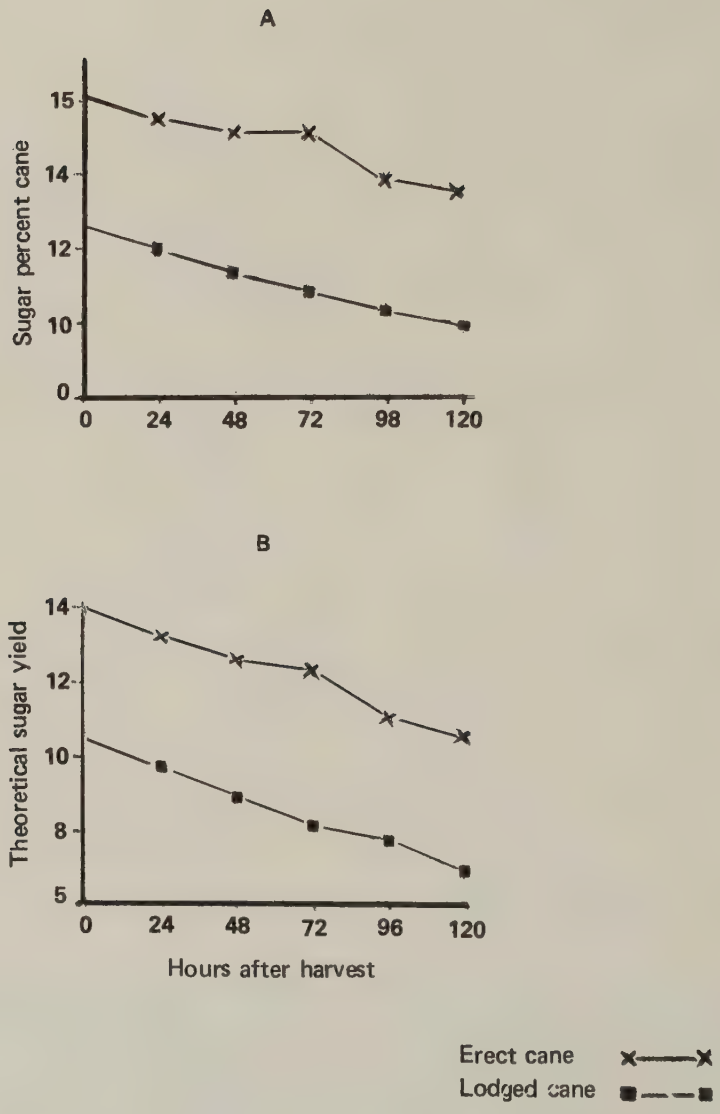

FIGURE 4. Changes in sugar percent cane and theoretical sugar yield with elapse of time after harvest.

the various indices with time elapsed seemed to be more or less the same in both erect and lodged cane. The only apparent exception was the change in the glucose ratio with the elapse of time after harvesting. The rate of increase in the glucose ratio in the lodge cane was higher than that in the erect cane. This may be due to the increase in sucrose inversion during the growth of lateral buds on the stalks of lodged cane.

The calculated over-all loss in theoretical sugar yield due to lodging

and rat damage from about 5 million tons of cane annually milled in Egypt was estimated at 14.615 tons of sugar if 10% of the cane milled was lodged and one percent of the lodged cane was damaged by rats.

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EFECTO DE ENCAMADO DE CAÑA Y DAÑO POR RATAS SOBRE CALIDAD DE CAÑA Y DETERIORO DESPUES DE COSECHAR

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RESUMEN

Al encamarse la caña se deprime la calidad de su jugo, pero el daño por ratas dió como resultado una merma más drástica en la calidad del jugo. El rendimiento teórico de azúcar de la caña encamada fúe reducido 17.2 por ciento comparado con 56.4 para caña encamada y dañada por ratas. Tanto la caña encamada como la encamada y dañada por ratas se deterioró a la misma tasa después de ser cortada.

METHODS OF PLANTING SUGARCANE FOR SUGAR AND BIOMASS PRODUCTION IN LOUISIANA

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ABSTRACT

Experiments were conducted to determine the effects of methods of planting on the yield and yield components of sugarcane. Single and multiple drill types of planting furrows were tested at widths of planting ranging from a V-furrow to 120 cm wide on standard row widths of 180 cm. Results indicated that the highest number of millable stalks and yield of stalks, sucrose, total biomass and fermentable sugars were produced from planting 4 drills, 90 cm wide with plant and stubble cane in one test and from 4 drills, 120 cm wide with plant cane in another test. The increases ranged up to 71.7% in stalk yield and 84.3% in sucrose yield over the V-furrow planting with plant cane. The highest yields produced were 178.6 tons of green weight and 40.0 tons of dry biomass per hectare and 15.3 tons of fermentable sugars per hectare with plant cane. Yields were increased substantially with wide single and multiple drill types of planting as compared to conventional V-furrow planting.

INTRODUCTION

Sugarcane is produced in Louisiana during a relatively short growing season due to climatic conditions. The crop usually grows from April until harvest time in October. Although cane grows rapidly during the summer and matures with a high sucrose content, the sugar yields are low due to short millable stalks and low cane yields.

Variety developments have increased the sugar content, but have not appreciably increased the stalk yield of sugarcane. Pest management and fertilization technology has helped to maintain current yields.

Previous work has indicated that sugarcane yields were closely related to the millable stalk population, especially in areas with a short growing season. Some cultural practices have been shown to increase stalk population and yield. Alternate methods of planting have the greatest potential to produce large increase in sugarcane stalk population and yield in Louisiana. The purpose of this paper is to present agronomic data obtained from experiments on

methods of planting sugarcane. The machinery development research involving methods of planting will be the subject of another paper.

MATERIALS AND METHODS

Experiments were conducted to determine the effects of methods of planting on the yields and yield components of sugarcane for sugar and biomass production. The tests were located on a Commerce silt loam soil on the Louisiana Agricultural Experiment Station at St. Gabriel, La. Experiment 1 was initiated with plant cane in 1977 and continued with first stubble cane in 1978. Experiment 2 was initiated with plant cane in 1978. The methods of planting studied involved the types and widths of planting furrows (Table 1).

The types of planting furrows or number of drills in each test were single and multiple drills on standard rows 180 cm wide. In Experiment 1, the multiple drills were planted with one line of seed cane in each drill spaced 30 cm apart. The total widths of the single and multiple drill types of furrows were 30, 60, 90 and 120 cm.

TABLE 1. Experiments conducted on methods of planting sugarcane on Commerce silt loam soil at the Louisiana Agricultural Experiment Station, St. Gabriel, Louisiana in 1977-78.

	Experiment 1. Plant and stubble			Experiment 2. Plant cane		
Treatment No. 1/	No. of drills	Drill spacing (cm)	Total width (cm)	No. of drills	Drill spacing (cm)	Total width (cm)
1	1	–	V	1	–	V
2	1	–	30	1	–	40
3	2	30	30	2	40	40
4	1	–	60	1	–	60
5	3	30	60	1	–	80
6	1	–	90	3	40	80
7	4	30	90	1	–	120
8	1	–	120	4	40	120
9	5	30	120	–	–	–

1/ *The number and spacing of drills shown for each treatment was planted on rows 180 cm wide.*

In Experiment 2, the multiple drills were planted with one line of seedcane in each drill spaced 40 cm apart. The total widths of the single and multiple drills were 40, 80 and 120 cm. In both tests, the same amount of seed cane was planted in the single and multiple drills for each total furrow width. A standard V-furrow with one drill was planted as a check treatment in each test.

The plots were 21.6 cm long and 3 rows wide with 4 replications of each treatment. Variety CP 65-357 was planted in October and harvested in November of the following year in each test. Standard cultural practices were used after planting the cane.

Yield and yield components were measured at harvest time on each plot. The plant number of population was determined by counting the millable stalks. The plant height, stalk diameter and individual stalk weights and the percentage of stalks, tops and leaves were measured on 20-stalk samples. The stalk yield was measured in the field by weighing the cane with tractor-mounted scales. The biomass yield was calculated from the plant weights and number of stalks per hectare.

The sucrose content of the cane juice was measured by the polariscope method to calculate sucrose yield. The percentages of sucrose, glucose and fructose sugars were measured by the liquid chromatograph method to determine the yield of fermentable sugars. The stalk fiber yield was determined by washing and drying bagasse samples.

RESULTS AND DISCUSSION

Yield Components

Results obtained on yield components in each experiment are reported in Table 2. The V-furrow treatment produced a significantly lower number of millable stalks at harvest than the other treatments in each test. In Experiment 1, with plant cane and stubble cane, the maximum number of stalks was produced with the 4 drills, 90 cm wide planting. The cane on the wider drills was damaged during cultivation and did not produce the highest plant population. In Experiment 2, the maximum population was produced with the 4 drills, 120 cm wide planting. The plant height, measured at the last visible dewlap, increased in most cases with increasing width of drills and plant population. The differences in stalk diameter and weight due to the treatments were not significant.

Stalk and sucrose yield

Results obtained on stalk and sucrose yield in each test are reported in Table 3. The V-furrow treatment produced the lowest yield of stalk and sucrose in each test. In Experiment 1, the 4 drills, 90 cm wide planting produced the largest increases of 71.7% and 52.7% in stalk yield and 84.3% and 59.3% in sucrose yield over the V-furrow with plant and first stubble cane respectively. In Experiment 2, the 4 drills, 120 cm wide planting produced the largest increases of 45.9% in stalk yield and 41.9% in sugar yield over the V-furrow. The percent sucrose in the cane juice determined by the polariscope method was not significantly affected by the methods of planting. The stalk and sucrose yields were closely associated with the number of millable stalks per hectare.

Total biomass yield

The data obtained on green and dry biomass yields in each test are reported in Table 4. The V-furrows produced the lowest biomass yield. In Experiment 1, the 4 drill, 90 cm wide planting produced a maximum yield

TABLE 2. Effects of methods of planting on the yield components of sugarcane.[1]

No. of drills	Width of drills (cm)	Plant		Stalk	
		Number (1000/ha)	Height (cm)	Diameter (cm)	Weight (kg)
		Exper. 1, Plant cane, 1977			
1	V	76.7	262	2.1	0.85
1	30	97.9	278	2.1	0.91
2	30	79.5	276	2.0	0.96
1	60	104.4	267	2.2	0.92
3	60	103.7	281	2.2	0.87
1	90	92.7	287	2.1	0.89
4	90	120.6	291	2.2	0.90
1	120	96.6	290	2.1	0.91
5	120	97.2	297	2.2	0.90
LSD 5%		11.5	12	NS	NS
		Exper. 1, First stubble, 1978			
1	V	60.4	245	2.3	1.18
1	30	81.5	246	2.3	1.03
2	30	83.0	258	2.4	1.12
1	60	87.2	256	2.4	1.00
3	60	85.0	262	2.4	1.02
1	90	89.4	269	2.3	1.03
4	90	91.7	273	2.4	1.18
1	120	86.3	263	2.4	1.10
5	120	76.3	259	2.3	0.93
LSD 5%		8.3	8	NS	NS
		Exper. 2, Plant cane, 1978			
1	V	77.3	276	2.6	1.26
1	40	88.4	286	2.6	1.07
2	40	88.7	296	2.4	1.24
1	60	88.7	290	2.6	1.09
1	80	95.1	294	2.5	1.09
3	80	97.8	288	2.6	1.10
1	120	95.6	295	2.6	1.08
4	120	103.0	286	2.6	1.15
LSD 5%		9.6	9	NS	NS

1 *Measured at harvest time.*

TABLE 3. Effects of methods of planting on the stalk and sucrose yields of sugarcane.

No. of drills	Width of drills (cm)	Stalk Yield (Ton/ha)	Stalk Inc. (%)	Juice sucrose[1] (%)	Sucrose Yield (Ton/ha)	Sucrose Inc. (%)
		Experiment 1, Plant Cane, 1977				
1	V	64.3	–	14.2	6.4	–
1	30	97.5	51.6	15.1	10.5	64.1
2	30	91.6	42.5	14.7	9.6	50.5
1	60	91.1	41.7	14.3	9.2	43.7
3	60	104.3	62.2	14.6	10.7	69.8
1	90	102.3	59.1	14.4	10.4	62.5
4	90	110.4	71.7	15.0	11.8	84.3
1	120	89.7	39.5	14.7	9.4	46.9
5	120	88.7	37.9	14.3	8.9	39.1
LSD 5%		13.7	–	NS	1.1	—
		Experiment 1, First stubble, 1978				
1	V	60.3	–	14.9	5.9	–
1	30	71.2	18.1	15.5	7.3	23.7
2	30	73.2	21.4	15.9	7.7	30.5
1	60	73.6	22.1	15.6	7.6	28.8
3	60	73.4	21.7	15.6	7.6	28.8
1	90	78.6	30.3	15.7	8.2	39.1
4	90	92.1	52.7	15.4	9.4	59.3
1	120	74.0	22.7	16.8	8.3	40.7
5	120	62.1	3.0	15.7	6.5	10.2
LSD 5%		9.9	—	NS	0.7	—
		Experiment 2, Plant cane, 1978				
1	V	70.6		15.9	7.4	–
1	40	74.9	6.1	15.6	7.7	4.1
2	40	86.1	22.0	14.7	8.3	12.2
1	60	83.4	18.1	16.5	9.2	14.3
1	80	95.6	35.4	15.9	10.1	36.5
3	80	97.2	37.7	16.2	10.5	14.9
1	120	90.0	27.5	15.5	9.2	24.3
4	120	103.0	45.9	15.4	10.5	41.9
LSD 5%		11.3	—	NS	0.8	—

1 *Sucrose by polariscope method.*

TABLE 4. Effects of methods of planting on the total biomass yield of sugarcane.

No. of drills	Width of drills (cm)	Total yields[1] Green (T/Ha.)	Total yields[1] Dry (T/Ha.)	Green yield in Stalks (%)	Green yield in Tops[2] (%)	Green yield in Leaves (%)
		Experiment 1, Plant cane, 1977				
1	V	87.1	21.3	74.3	2.2	23.5
2	30	120.6	28.2	75.7	1.9	22.4
3	60	126.4	29.5	80.6	1.2	18.2
4	90	136.9	31.3	80.4	1.3	18.3
5	120	115.9	30.4	75.9	1.3	22.8
LSD 5%		23.6	6.7	—	—	—
		Experiment 1, First stubble, 1978				
1	V	103.6	23.0	68.8	5.0	26.7
1	30	121.3	29.6	69.0	3.8	27.2
2	30	132.4	32.6	70.2	4.3	25.5
1	60	126.6	31.1	71.3	4.9	23.8
3	60	122.1	29.4	68.7	4.9	26.4
1	90	135.2	32.4	71.0	3.8	25.2
4	90	152.9	36.8	70.7	3.9	25.4
1	120	127.8	33.0	69.5	4.5	26.0
5	120	108.1	27.3	67.8	4.3	27.9
LSD 5%		8.9	2.1			
		Experiment 2, Plant cane, 1978				
1	V	136.9	32.0	71.3	3.5	25.2
1	40	141.0	34.0	67.0	5.0	28.0
2	40	158.0	36.8	69.6	4.8	25.6
1	60	137.4	34.2	70.1	2.6	27.3
1	80	151.1	36.6	68.3	3.6	28.1
3	80	153.1	37.0	70.6	3.5	25.9
1	120	148.0	36.1	69.7	3.7	26.6
4	120	178.6	40.0	66.5	5.3	28.2
LSD 5%		11.1	2.6			

1 *Total above-ground growth.*

2 *Tops were immature internodes.*

of 136.9 tons of green yield and 31.3 tons of dry yield per hectare in plant cane and 152.9 tons of green yield and 36.8 tons of dry yield per hectare in stubble cane. In Experiment 2, the 4 drills, 120 cm wide planting produced the maximum yield of 178.6 tons of green yield and 40.0 tons of dry yield

TABLE 5. Effects of methods of planting on the fermentable sugar and fiber yields of sugarcane.

No. of drills	Width of drills (cm)	Fermentable sugars[1] Stalk (%)	Juice (%)	Yield (Ton/ha)	Fiber Stalk (%)	Yield (Ton/ha)
		Experiment 1, First stubble, 1978				
1	V	15.1	17.4	9.1	13.4	8.1
1	30	15.0	17.3	10.7	13.3	9.5
2	30	16.1	18.4	11.8	12.4	9.1
1	60	15.5	17.9	11.4	13.4	9.9
3	60	14.2	16.4	10.4	13.2	9.7
1	90	14.9	17.2	11.7	13.4	10.5
4	90	15.9	18.4	14.6	13.4	12.3
1	120	15.9	18.2	11.8	12.7	9.4
5	120	15.5	18.4	9.6	15.8	9.8
LSD 5%		NS	NS	1.0		0.7
		Experiment 2, Plant cane, 1978				
1	V	16.1	18.8	11.4	14.4	10.2
1	40	14.9	17.3	11.2	13.6	10.2
2	40	15.0	17.3	12.9	13.4	11.5
1	60	14.4	16.7	12.0	13.8	11.5
1	80	14.3	16.3	13.7	12.5	12.0
3	80	14.2	16.2	13.8	12.7	12.3
1	120	14.4	16.8	13.0	14.0	12.6
4	120	14.9	16.8	15.3	11.3	11.6
LSD 5%		NS	NS	1.2	—	1.0

1 *Sucrose, glucose and fructose sugars determined by the liquid chromatograph method*

per hectare. The difference in percent stalks, tops and leaves due to the planting methods were small. The average percentages of stalks, tops, and leaves in the total green biomass were 77.4, 1.6 and 21.0, with plant cane in Experiment 1, 69.7, 4.4, and 25.9 with stubble in Experiment 1, and 69.1, 4.0. and 26.9 with plant cane in Experiment 2. The stalks consisted of the millable stalks topped at the last hard internode and the tops consisted of immature internodes.

Fermentable sugars and fiber yield

The data obtained on fermentable sugars by the liquid chromatograph method and the fiber content of the stubble cane in Experiment 1 and plant cane in Experiment 2 are reported in Table 5. Differences in the percentages of fermentable sugars in the cane juice due to methods of planting were small. The average fermentable sugar contents in both tests were 15.1% in the stalks

and 17.4% in the juice. The sugars in the juice consisted an average of 16.2% sucrose, 0.7% glucose and 0.5% fructose. The sugar analyses were made on fresh cane when apparently 83.1% of the sugars was in the sucrose form. The highest fermentable sugar yields produced were 14.6 tons per hectare from the 4 drills, 90 cm wide planting in Experiment 1 and 15.3 tons per hectare from 4 drills, 120 cm wide planting in Experiment 2. The differences in percentages of fiber in the stalks were small. The highest yield of fiber per hectare was produced by the same types of planting that produced the highest sugar yields.

Generally the results indicated that the stalk, biomass and sugar yields can be increased substantially in Louisiana with wide planting on conventional rows 180 cm wide. Four lines of seed cane per row planted 90 cm wide in either a single wide furrow or in multiple drills appeared to be the most practical method of planting to increase yield. This means that one-half of the surface area of each row was actually planted, which allowed ample space between rows to operate cultivation and harvesting equipment. Cane growing in drills wider than 90 cm was easily damaged during cultivation and difficult to harvest mechanically. Single wide furrows can be planted with mechanical planters, but it is difficult to properly cover the seed cane with soil. Multiple drills must be planted with hand labor, but it is easy to cover the seed cane without squeezing the seed into a narrow drill.

METODOS DE SEMBRAR CAÑA DE AZUCAR PARA LA PRODUCCION DE AZUCAR Y BIOMASA EN LOUISIANA

R. Ricaud y B. J. Cochran

RESUMEN

Se llevaron a cabo experimentos para determinar los efectos de diferentes metodos de siembra sobre el rendimiento y los componentes de rendimiento de caña de azucar. Se ensayaron siembras en hileras sencillas y multiples, variando desde un sucro en forma de V hasta un ancho de 120 cm en hileras normales de 180 cm de ancho. Los resultados demostraron que el mayor numero de tallos aptos para el molino y rendimiento de tallos, sacarosa, total de biomasa y azucares fermentables fueron producidos sembrando 4 hileras, 90 cm de ancho con plantilla y retoño en una prueba y con 4 hileras, 120 cm de ancho con plantilla en otra prueba. Los aumentos variaron hasta 71.7% en rendimiento de tallos y 84.3% en rendimiento de sacarosa sobre la siembra en sucros en forma de V en plantilla. Los rendimientos mas altos producidos fueron 178.6 toneladas de materia

verde y 40.0 toneladas de biomasa seca por hectarea y 15.3 toneladas de azucares fermentables por hectarea en plantillas. Los rendimientos fueron aumentados substancialmente con siembras en hileras anchas y sencillas y multiples en comparacion con la forma convencional de sembrar en sucros en forma de V.

MUMIAS OUTGROWERS SCHEME: A STUDY IN SELF-SUFFICIENT SUGARCANE PRODUCTION

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ABSTRACT

The Mumias Sugar Company in Western Province, Kenya started production of sugar in 1973. Capacity has been expanded in three stages from 45,000 tons of sugar per year to 180,000 tons sugar per year. Initially, 50% of the cane supply was provided by small farmers. The success of the small farmer outgrower scheme has made it possible to organize all the cane supply for the successive expansion in capacity from small farmers. At the present time over 12,500 farmers within a 20-km radius of the factory grow 18,600 hectares of cane which will supply 1,400,000 tons of cane annually. This represents 87.5% of the total factory requirement. The scheme is based on the provision of inputs by the company on credit basis and the farmer provides his land and the manual labor inputs for the crop. The organization of the scheme and the financial results for the outgrower farmers are described.

INTRODUCTION

The Mumias sugar scheme in Western Kenya has attracted considerable interest because of its almost unique dependence on cane produce by small-scale farmers. The factory will grind 1.60 million tons of cane this year with 1.40 million tons to be supplied by farmers with an average cane growing area of less than 1.5 hectares.

The scheme is located at Mumias in Kakamega district of Western Province about 400 kms Northwest of Nairobi. A pre-feasibility study was carried out in 1964-65. In 1967, a detailed feasibility study and pilot project was begun by Bookers Agricultural and Technical Services under contract to the Kenya Government. The objectives of the project to be evaulated included creation of wage and employment, promotion of import-saving industry, achievement of self-sufficiency in sugar production, and to provide a further source of cash income for farmers. It is this latter requirement that this paper will concentrate on.

DEVELOPMENT OF SCHEME

During the feasibility study period (1967-1970), a survey of potential

growers of cane was carried out and 46 demonstration plots of cane were established. The land of farmers who expressed interest to become cane growers was assessed for suitability for cane growing. The survey which was restricted to an area within an 8 mile radius of Mumias, revealed a very active and lively interest in cane growing, and that adequate suitable land was available for cane.

In the report submitted by the consultants, it was recommended that about one half of the cane requirements of the initial factory (with a production of 45,000 tons of sugar) per year should be grown on small farmers land, and the balance from a nucleus estate owned by the company. There have been three subsequent expansions of the factory. The first expansion took capacity from the initial 80 tons per hour to 125 tons per hour in 1976. The next expansion increased crushing capacity to 150 tons per hour in 1978, and the final expansion completed in June, 1979 doubled capacity to 300 tons cane per hour.

Corresponding rated annual sugar productions were: 1973 – 45,000 tons, 1976 – 75,000 tons, 1978 – 90,000 tons, 1979 – 180,000 tons. Annual cane requirement has increased from 400,000 tons per year at the outset to 1,600,000 tons at the present time. Because of the successful response by farmers in the area, all the expansion of capacity has been supplied from farmer grown cane. About 12,500 farmers are now contracted outgrowers of Mumias Sugar Company, growing a total of 18,600 hectares of cane. (Figures 1 and 2).

The area has been transformed by the introduction of commercial cane. At the outset the area was a seriously under-developed area. Land utilization was poor. The farmers grew small areas of food crops but bush and rough grass predominated. Such crops as were grown were almost entirely subsistence crops. The relative remoteness of the area and poor communications had prevented the development of an active market economy. However, there was one very important factor in favor of the development proposed. Land adjudication had been carried out and the farmers had freehold title to their land. The average size of holding was about 4 hectares, which is relatively large for Western Kenya, reflecting the unprofitable nature of the farming activity at that time. The combination of rainfall, altitude, and soils at Mumias is not particularly favorable for traditional cash crops, but is reasonably suitable for sugarcane. The rainfall averages about 2000 mms per year uniformly distributed. The average maximum temperature is 29.4°C and the average minimum temperature is 14.1°C. The low average temperature results in slow cane growth and slow maturity, but sunshine hours are high, and high purity juices are standard throughout the year. The soils have poor reserves of plant nutrients but cane yields respond well to quite modest levels of fertilizer application.

ORGANIZATION OF OUTGROWER FARMING SYSTEM

Under these circumstances, the farmer could offer his experience as a cultivator, his labor and the labor of his family, and his land. He had no machinery and virtually no cash resources for the purchase of inputs. It was necessary

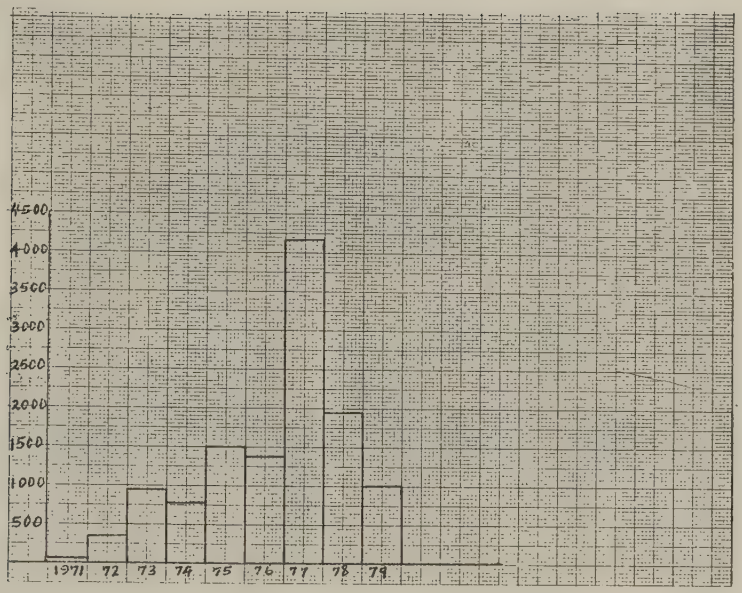

FIGURE 1. Number of Sugarcane farmers recruited as contracted outgrowers at Mumias Sugar Company

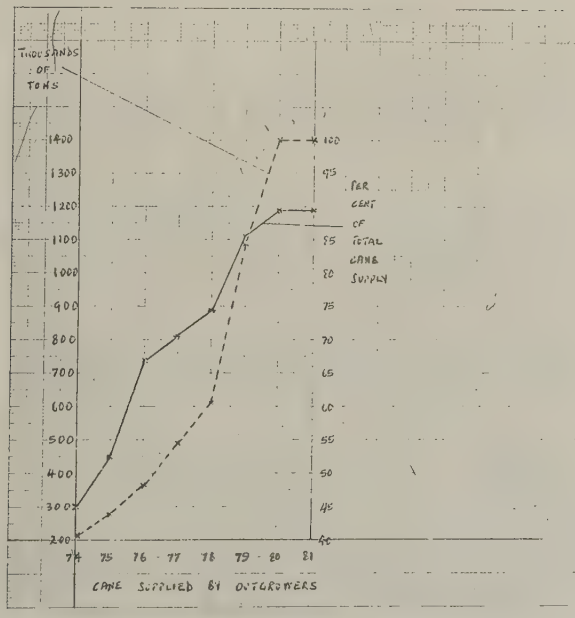

FIGURE 2. Canes supplied by farmer outgrowers

to find a way for the purchase of inputs to be made available easily to the farmer, and combined with the farmers own resources. The basis of the solution to the problem is for the company

a) to provide the machinery for land preparation
b) to supply the farmer fresh healthy planting material
c) to supply the farmer with the necessary fertilizers
and for the farmer to provide the manual labor inputs for:

(1) planting the cane setts
(2) applying fertilizer
(3) maintaining the crop in a weed-free condition.

The company provides an extension service to counsel and guide the farmer on the correct cultivation practices (and to try and ensure that these are performed thoroughly and on time), and organizes the cutting and transport of the farmers cane.

Any grower wishing to become a cane farmer is required to register with the company's outgrower services section. The land is inspected for suitability for cane growing. In addition to a visual assessment of the land, it is necessary to ensure that if the plot is not of sufficient size to constitute a field, then other adjacent farmers must be willing to be associated with the plot. Since a minimum field size of 6 hectares is set, few single owners can beat the requirement. A minimum plot size of 1 hectare is an objective but frequently less is accepted. The necessity for these minima is that for a field of less than 6 hectares, the operation of land preparation equipment is uneconomical. It should be noted that although a field may be comprised of the plots of several owners, the plots are distinct, and the growing of the cane remains the job of the individual plot owner.

When a field has been accepted for cane growing, the individual plot owners sign cane farming contracts and become contracted outgrowers. The contract sets out the obligations and rights of the farmer on one hand and of the sugar company on the other.

LAND PREPARATION AND CULTIVATIONS

The owner of the plot is obliged to remove bush and stumps. The company undertakes the ploughing, harrowing and furrowing necessary to create a proper seed bed for the cane. All the land preparation fleet consists of wheeled tractors, mainly 75 H.P. Heavier tractors cannot be economically operated on the small scattered fields, and tracked equipment is equally inappropriate. The land having been prepared, the company delivers seed cane and fertilizers to the field. The farmer organizes, under the guidance of a company employed headman, the planting and fetilizing. Later work consists of a top-dressing of fertilizer and manual weeding, and is the responsibility of the farmer. The company outgrowers staff in the field keeps a very close eye on the planting operation, and

subsequent cultivations to ensure that they are performed timely and in a thorough manner.

HARVESTING AND TRANSPORT

The climatic conditions at Mumias are such that there is a long planting season extending from early March to the end of October. Planting in November-February is usually avoided because one or more months in this period may be dry. The harvesting of the cane is performed by the company, as is the cane transport. All cane cutting is manual and outgrower cane is cut green. The cutters stack the cane in heaps of a size calculated to make 6 tons of cane. Two chains are placed round the bundle and a winching tractor rolls the bundle on to a trailer. For shorter hauls the tractor proceeds directly to the factory. For longer hauls, the cane bundle is transfered to a second trailer, carrying two bundles. Transfer from the single bundle trailer to the two bundle trailer is again done with a tractor fitted with a winch. All the trailers are attached to the tractors with a weight transfer hitch. A great deal of haulage is done in wet weather and the weight transfer system does assist mobility in wet conditions.

Cane bundles are tagged to identify the owner at cutting. These tags are attached to weighbridge tickets as the trailers enter the factory. Payment is made only on the basis of weight of cane delivered.

RATOON CULTIVATIONS

For the ratoon crops, cultivations are fairly simple. The trash has to be placed in the interrow to allow the cane shoots to develop. Fertilizers are applied. The trash blanket greatly limits weed growth, but some manual weeding is necessary. The farmer is responsible for trash lining, fertilizer application and any necessary manual weeding. The company supplies the fertilizer.

All services and goods supplied by the company are charged to the farmers account, and the cost is recovered at the time payment for the cane is made. The farmer pays interest for the value of credit received. It will be seen that the system is simple. It is deliberately kept this way, and part of the success of the scheme is due to its simplicity. Even so the task of organizing and administering for such a large number of individual farmers is considerable.

The system is deliberately labor intensive. The farms are small and the farmers' resources are limited; there is little opportunity for other employment. It is necessary to ensure that the farmers return represents as far as possible return for his own labor, and is not reduced by purchase of inputs which would substitute his own labor. The technical aspects of cane growing are looked after by the company agronomy unit which is constantly evaluating varieties and fertilizer treatments. There is caution about introducing new varieties, although the company is conscious of the danger of having such a massive

concentration of one variety, Co 421. An alternative variety must perform at least as well as Co 421 before releasing the latter to farmers. There was also reluctance to complicate fertilizer treatments. Remarkably good results over a wide range of soil types with a standard fertilizer treatment (plants 90 kilos N per ha 45 kilos P_2O_5 per ha) were obtained. Since the scheme is now moving into a second crop cycle, it was considered necessary to attempt a more sophisticated approach to fertilizing though this will probably consist of recommending additional fertilizer applications as indicated by soil or foliar analysis.

The normal crop cycle is plant plus 2 ratoons, and this may spread over a six-year period. Where second ratoon crops are still healthy and productive, a third ratoon is taken, and it could well be that a fourth ratoon will be possible from some fields in due course.

Harvest age of plant cane is in the range of 20-30 months, and of ratoon cane in the range of 16-26 months. These age ranges are perhaps unusually wide. Cane under the almost non-seasonal growing conditions at Mumias seldom flowers. High juice purity and pol of 13 + % are achieved at the lower ages indicated. Weight increments continue with only a slight slowing down to the top of the age range. This wide possible age range for harvesting does give considerable flexibility and this is necessary, as with all rain-fed growing system, yields can vary considerably, according to the rainfall received.

It will be noted that the very high per hectare yields recorded in 1978 are due to a combination of greater productivity (i.e. higher TCHM) and greater age at harvest. The increase in productivity is due to a large extent to the improved weather regime that has prevailed since early 1976, but there is little doubt that the contract farmers are becoming better cultivators of cane.

In the early stages of the project, farmers yields and producitivty were low compared with the nucleus estate (by about 20%). In 1978, farmers plant cane and ratoon cane were within 10% of nucleus estate, although 2R yields and productivity lagged considerably behind at 72% of nucleus. It is expected that as farmers became more experienced, and the impact of the company's extension work is more effective, the gap in performance between nucleus and outgrowers cane will narrow if not disappear.

The gross payment represents the gross proceeds of cane deliveries priced at the prevailing price for cane which is determined by government. Net payments represent cash actually paid by the Company to the outgrower after deducting costs of land preparation, seed cane supply, fertilizer supply and interest thereon; cost of harvesting, transport, and also since 1977 deduction of Mumias Outgrowers Company capital levy (see Financial Returns).

MUMIAS OUTGROWERS COMPANY

The formation of Mumias Outgrowers Company was stimulated by Government, effectively in 1976. The primary objectives are two-fold.

TABLE 1. The cane yields over the years.

	1973	1974	1975	1976	1977	1978
			Tons per hectare			
Plant	137	126	105	113	144	180
1R	–	76	82	90	116	147
2R	–	–	–	64	88	113

TABLE 2. Expressed as tons of cane per hectare per month. The pattern for the last four years is:

	1975	1976	1977	1978
Plant	4.74	5.0	5.9	6.5
1R	4.2	4.5	5.7	6.2
2R	–	3.6	4.5	5.0

(1) to establish an organization which can effectively represent the interests of the outgrowers with Mumias Sugar Company, Government and other outside bodies.

(2) to finance outgrower credit. To this end MOCO has borrowed from Government, CDC, and the Kenya Commercial Bank, with MSC guaranteeing the borrowings. These sources still leave a shortfall in the total credit requirement which has been made good by MSC. The capital levy (presently 6Ss per ton) is paid to enable MOCO to meet its debt repayment obligations.

In addition MOCO takes an interest in the whole farm activities of its members, and has plans to influence the way in which the sales cane proceeds are utilized.

FINANCIAL RETURNS

Kenya Shillings (1 KSs = $0.133)

	1974	1975	1976	1977	1978
Gross payment/ hectare					
Plants	7,893.96	9,683.76	11,961.64	18,363.64	23,937.36
Ratoon I	5,000.47	7,013.43	9,192.89	13,999.83	19,540.18
Ratoon II	–	–	6,616.86	11,474.41	15,004.03
Ratoon III	–	–	–	–	8,472.33
Average KSs	7,824.35	8,612.23	10,071.29	14,929.63	20,069.73
Average $	1,040.64	1,145.43	1,339.48	1,985.64	2,669.27
Net Payment/ hectare					
Plants	3,161.25	4,239.20	4,713.67	8,848.40	12,092.78
Ratoon I	1,575.37	3,879.29	4,139.66	7,060.20	11,026.03
Ratoon II	–	–	2,493.80	5,673.39	8,408.65
Ratoon III	–	–	–	–	5,132.84
Average KSs	3,123.10	4,094.78	4,219.84	7,327.07	10,706.86
Average $	415.37	544.60	561.23	974.50	1,424.01
Gross Payment/ Ton					
Plants	62.00	92.00	105.00	129.82	133.00
Ratoon I	62.00	92.00	105.00	124.05	133.00
Ratoon II	–	–	105.00	131.03	133.00
Ratoon III	–	–	–	–	133.00
Average KSs	62.00	92.00	105.00	128.58	133.00
Average $	8.246	12.236	18.965	17.101	17.689
Net Payment/ Ton					
Plants	24.82	40.27	41.37	62.55	67.18
Ratoon I	19.53	50.88	47.28	62.56	75.04
Ratoon II	–	–	39.57	64.79	74.53
Ratoon III	–	–	–	–	80.57
Average KSs	24.74	43.74	43.99	63.10	70.95
Average $	3.245	5.817	5.851	8.392	9.436

KEY FACTORS IN SUCCESSFUL DEVELOPMENT

1. *Careful Project Planning.* The feasibility study and pilot project work were conducted thoroughly over a sufficient period of time to enable a blue print for project development to be prepared.

2. *Indigenous Population.* The indigenous population are essentially farmers. Prior to the introduction of the scheme they had little awareness of science-based agriculture, and no resources to practice it. But being farmers they have responded well and willingly adopted the new farming practices which have been introduced.

3. *Relationship between Government, Company and Management.* The responsibilities of the various parties involved have been clearly defined. Policy is primarily determined by the government as the majority shareholder. Implementation of policy is clearly the responsibility of the contracted managers. Monitoring of management performance is the responsibility of the board.

4. *Adequate finance.* The flow of funds to finance the project development has in general been adequate and timely. There has been no interruption to development program because of fund shortages, although minor adaptations have been necessary from time to time.

5. *Profit-based operation.* The organization of outgrower development relates returns to the individual farmer directly to the individual farmer's success as a cane grower.

6. *Control of Mumias Sugar Company.* The company's interest is in ensuring in both the short and the long term that cane sufficient to fill the factory capacity is available. The orderly development of outgrower farming by the contract system helps to ensure this; close control by the company ensures that a very large proportion of the farmers produce good crops which are profitable, and this in turn ensures the long term cane supply prospects.

POSSIBLE FUTURE DEVELOPMENTS

It is considered that the scale of present sugar production operations cannot be significantly expanded. The collection radius for cane, given the existing roads infrastructure is as large as is economically viable.

It will be necessary for the outgrowers scheme to adapt to changing conditions in the 1980's. They may require some amalgamation of holdings so that the average cane plot size is increased beyond the present 1.5 hectare level.

It may also be necessary, because of diminishing availability of labor, to introduce a greater degree of mechanization. There is some prospect that

the Mumias Outgrowers Company may take over the provision of some of the services performed by Mumias Sugar Company, so that the cane supply contractor is MOCO rather than the individual outgrower. In any event, it is believed that the scheme having been soundly established will be able to make any adaptation which is necessary to meet changing external conditions.

EL PROGRAMA DE PRODUCTORES DE CAÑA DE MUMIAS

A. Beevers

RESUMEN

Mumias Sugar Company, en la Provincia Occidental Kenya. comenzo a producir azucar en 1973. Su capacidad ha sido expandida en tres etapas desde 45,000 toneladas de azúcar por año hasta 180,000 toneladas de azucar por año. Inicialmente 50% de la caña era suplida por pequeños agricultores. El exito del programa de los pequeños agricultores productores de caña hizo posible que las sucesivas expansiones en capacidad se hicieran a base de la caña producida por estos pequeños productores. Actualmente mas de 12,500 agricultores en un radio de 20 km de la factoria cultivan 18,600 hectareas de caña, que suplen 1,400,000 toneladas de caña anualmente. Esto representa 87.5% del requerimiento total de la factoria. Este programa esta basado en creditos que ofrece la compania, mientras que el agricultor dispone su terreno y mano de obra. Se describe la organizacion de este programa y los resultados financieros para los agricultores productores de caña.

THE SIGNIFICANCE OF SOIL NON-EXCHANGEABLE POTASSIUM IN RELATION TO SUGARCANE GROWTH

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ABSTRACT

Of the total of 217 field experiments on potassium fertilization conducted in 1963/64-1972/73, 34 plots showed significant responses to K application. Based on those plots showing K response, it was found that non-exchangeable soil K was highly correlated with sugarcane yield though it only averaged 1.14% of the total K of the soils tested.

Modifications of the procedure of Hunter and Pratt's No. 1a method have been made to extract non-exchangeable soil K. The extraction of water soluble and exchangeable K were also included in this test.

Coefficient of correlation ($r = 0.7014$) between the non-exchangeable K obtained from the modified method, and cane yield % under field condition was significant at 0.1% level. The modified procedure for non-exchangeable soil K test was superior to Hunter and Pratt's original method in some aspects such as, the reduction of soil sample weight and the amount of concentrated H_2SO_4 being used, facility of analytical work and applicability to sugarcane fields irrespective of soil types.

The modified procedure of non-exchangeable soil K determination may be described as follows:

Place 2.5g of soil into a 100ml beaker, add 15ml of H_2O, then 5ml of concentrated H_2SO_4 is slowly added and stirred up. Stand for 30 min., add 30 ml of H_2O and filter directly. The filtrate is determined with flame photometer.

INTRODUCTION

Sugarcane requires large quantities of K for its growth. Yang[18] reported than an average of 4.78 kg K_2O is needed to produce one ton cane. In Taiwan, the rate of K fertilizer applied for sugarcane averages 100 kg K_2O/ha, an amount far less than is required.

For many years, it was believed that the supply of K to crops was mainly in the forms of water soluble and exchangeable K in the soil. The importance of non-exchangeable soil K was underestimated. As sugarcane is a perennial crop, supplementary application of K fertilizer is frequently needed as the exchangeable K content of most soils commonly cannot meet the requirements of continued cropping. Therefore, non-exchangeable K in the soil should play an important role in supplying K to sugarcane because this form of K tends to be released as soluble K or exchangeable K when its levels in the soil are decreased.

Release of non-exchangeable K has been studied by many researchers (Ayres[1,2], Bray and DeTurk[5], and Cook and Hutcheson Jr.[6], Doll *et al*[8] Tahatabia and Hanway[14], Wood and DeTurk[17]). When exchangeable K is removed from the soil, the release of readily available non-exchangeable K may be quite rapid (MacLean and Simon[12]). Crabtree[17] illustrated that under intensive cropping, about one-half of the K taken up by the plants was from a non-exchangeable form. Apparently exchangeable K and non-exchangeable K are equally important to plant growth.

There are numerous reports from field experiments which showed an excellent correlation between exchangeable soil K and crop yield. This study is to compare various methods for the determination of forms of K in the soil in relation to cane yield and to establish a practical method for routine K test for sugarcane soils of Taiwan Sugarcane's plantations.

METHODS AND MATERIALS

Layout of field plots and soils

Thirty four out of a total of 217 K fertilizer field experiments conducted in 1963/64-1972/73 by Taiwan Sugar Research Institute have shown sugarcane responses to K fertilization by significant differences. Locations, general soil characteristics and cane yield are shown in Table 1. It covered six major soil types of sugarcane growing areas with pH ranging from 5.4 to 8.1. Field experiments were designed either as Latin squares of randomized complete blocks. The plots consisted of 8 rows, each row being 5-10 m long and having a 1.25 m distance in-between. Rates of fertilizers which varied with crop years were as follows:

$N : P_2O_5 : K_2O$ = 200 : 103 : (0, 66, 132, 198) in 1964/65-1969/70,
= 250 : 100 : (0, 100, 150, 200) in 1971/72-1972/73,
= 250 : 100 : (0, 100, 200, 300) in 1970/71,
= 250 : 100 : (0, 100, 200, 300) in 1963/64-1972/73.

Analytical methods used

(1) Water soluble K from saturation extract (Black[4] and USDA[16])

(2) Neutral 1 N NH_4OAc extractant (Black[4] and Jackson[11])

TABLE 1. General soil characteristics and cane yield of field experiments showing K response in 1963/64-1972/73.

Soil No.	Sugar mill	Plantation and field No.	Soil@ group	pH	Texture	Cane yield, t/ha		% yield of cane
						K_0	K_{max}	
1.	Hsiaokong	Sichu 25	H	7.4	sicl	88.4	106.4	83.1**
2.	Hsiaokong	Kaosung 24	H	7.7	sicl	121.6	132.4	91.8*
3.	Machia	Lungtein 23	H	7.1	sil	120.9	149.9	80.7**
4.	Hsiaokong	Kuopei 24	H	7.8	sicl	58.3	70.4	82.8**
5.	Hsiaokong	Fengkong 24	H	8.1	sicl	104.3	117.5	88.8**
6.	Kaohsiung	Chinfeng Wuchiawei 5	AS_c	7.7	sil	60.2	70.6	85.3*
7.	Shanhua	Chuochia 14	AS_c	5.5	sil	99.6	111.0	89.7*
8.	Suantou	Suantou 19	AS_c	7.2	l	105.1	122.8	85.6**
9.	Wushulin	Anchi 20	AS_c	8.1	l	92.3	107.8	85.6**
10.	Nanchou	Sansiho 4	ATL	7.8	sil	112.5	136.2	82.6**
11.	Chihu	Yuanan 13	ATL	7.9	sicl	134.6	152.7	88.2**
12.	Chihu	Chunghsi 16	ATL	7.8	l	140.2	156.3	89.7**
13.	Chishan	Tuku 57	ATL	7.9	sil	117.9	146.6	80.4**
14.	Pingtung	Chunglan 23	ATL	6.6	l	74.2	88.2	84.1**
15.	Nanchou	Kanting 26	ATL	6.1	sil	143.0	170.8	83.7**
16.	Chihu	Erhlin 43	ATL	8.0	l	101.0	126.2	80.0**
17.	Chihu	Erhlin 43	ATL	7.9	l	107.4	130.4	82.4*
18.	Kaohsiung	Houchin Chutzumen 8	AS_n	7.3	sl	85.4	96.7	88.3**
19.	Taichung	Wantouliu 33	AS_n	6.9	sicl	97.9	131.6	74.4**
20.	Kaohsiung	Hsichingpu Chingpu 11	RY	6.4	sil	169.8	190.6	89.1**
21.	Shanhua	Chiapa 12	RY	5.9	sl	107.4	126.2	85.1**
22.	Kaohsiung	Hsichingpu Hsinantzu 2	RY	6.9	sl	98.6	119.4	82.6**
23.	Kaohsiung	Tungchingpu Chiwei 6	RY	6.7	sl	107.1	123.8	86.5**
24.	Kaohsiung	Tungchingpu Chiwei 3	RY	7.2	sl	154.5	169.8	91.0**
25.	Kaohsiung	Hsichingpu Hsinantzu 2	RY	6.6	sl	85.8	98.6	87.0**
26.	Shanhua	Napalin 4	RY	5.4	sil	42.8	57.3	74.7**
27.	Shanhua	Napalin 4	RY	5.5	sil	55.0	75.0	73.3**
28.	Chishan	Yuehmei 27	RY	5.5	sicl	98.9	123.1	80.3**
29.	Chishan	Yuehmei 27	RY	5.4	sicl	63.3	77.3	81.9*
30.	Kaohsiung	Hsichingpu Chingpu 27	RY	6.3	sicl	83.2	106.6	78.1**
31.	Kaohsiung	Hsichingpu Chingpu 27	RY	6.0	sicl	64.6	78.2	82.6**
32.	Touliu	Kanchiao 30	R	6.8	l	90.0	109.0	82.6**
33.	Touliu	Kanchiao 30	R	6.5	l	62.4	91.6	68.1**
34.	Talin	Tapumei Chungkeng 60	R	5.8	l	80.6	97.6	82.6**

@:H: Low humic gley soil; AS_c: Sandstone alluvial, calcareous soil;
ATL: Slate, sandstone and shale alluvial soil; RY: Red yellow podzolic soil;
AS_n: Sandstone alluvial, non-calcareous soil; R: Red soil.
** Significance at 5% level.*
*** Significance at 1% level.*

(3) H. S. P. A. method with Neutral 1 N NH_4OAc, 1:20, 10 min by the Hawaiian Sugar Planters Association.

(4) Hunter and Pratt's No. 1 with cold H_2SO_4, (Black and Hunter and Pratt[10])

(5) Mehlich's method with 0.05N HCl + 0.025N H_2SO_4, 1:4, 5 min (Tseng[15])

(6) Louisiana method with 0.1 N HCl, 1:20, 5 min.

(7) Wood & DeTurk's method with Boiling 1 N HNO_3, 1:10, 10 min (Black[4] and Wood and Deturk[17])

(8) Hunter and Pratt's No. 1a method (Hunter and Pratt[10])

(9) Total K (digested with HF-$HClO_4$) (Black[4])

RESULTS AND DISCUSSIONS

Extractable soil K in relation to cane yield %

Based on the results of the 34 experiments, five extractants were used to test their correlations to soil exchangeable K and cane yield. Table 2 shows the measurements of extractable K determined with various procedures. The correlations are indicated in Table 3, which showed that under intensive cropping, the exchangeable soil K was not well correlated with sugarcane growth. Neutral 1 N NH_4OAc, 1:10, shaking for 30 min, has been used in the Institute for years as a soil K test method on TSC's farms. Its correlations coefficient (R) with cane yield % however, was found to be only 0.1602. The methods of determination of soil K used by H. S. P. A., Louisiana and Mehlich were also not applicable to the soils of TSC's plantations.

Since non-exchangeable K is known to be released easily in an available form, it seems logical that non-exchangeable soil K could be correlated well with cane yield.

Correlation between various forms of soil K and cane yield %

Table 4 shows the values of various forms of soil K. The total K content of the soils tested ranged from 8,000-25,100 ppm (or 0.8-2.51%) K. The greatest quantity (more than 98%) of each of these forms of K in the soil is in mineral form. The water content of soluble K in these soils was extremely low ranging from a high of only 13 ppm to a low of 2 ppm. Exchangeable K content as % of total only accounted for 0.19 which is much less than the measurement reported by Bear, *et al*[3]. Slate alluvial soil (ATL) contained the highest quantity of exchangeable K which only averaged 0.77% of the total K. For all the 34 soils, however, 1.14% of the total K was found in the form of non-exchangeable K.

TABLE 2. Soil potassium extracted with various extractants (ppm, K)

Soil No.	Soil group	1 N NH_4OAc 1:10, 30 min.*	1 N NH_4OAc 1:10, combine 3 extracts**	H.S.P.A.	Mehlich	Louisiana
1.	H	36	36	34	25	42
2.	H	46	43	44	25	51
3.	H	25	23	24	19	31
4.	H	34	34	34	21	46
5.	H	60	59	40	26	68
6.	AS_C	40	35	36	28	54
7.	AS_C	34	32	31	24	34
8.	AS_C	36	34	32	28	40
9.	AS_C	44	42	42	21	54
10.	ATL	22	20	18	16	35
11.	ATL	24	22	18	8	50
12.	ATL	22	20	18	20	32
13.	ATL	21	21	18	15	31
14.	ATL	18	18	16	16	22
15.	ATL	28	28	26	24	32
16.	ATL	8	11	11	10	18
17.	ATL	9	10	9	8	15
18.	AS_n	35	32	31	27	40
19.	AS_n	40	38	37	33	44
20.	RY	40	34	34	28	38
21.	RY	55	50	52	45	53
22.	RY	51	49	47	44	52
23.	RY	34	32	31	28	36
24.	RY	51	48	48	43	56
25.	RY	40	38	36	33	42
26.	RY	22	22	22	19	22
27.	RY	33	30	30	27	30
28.	RY	36	36	34	27	33
29.	RY	43	43	40	34	41
30.	RY	26	28	26	21	28
31.	RY	28	28	27	24	31
32.	R	54	49	49	41	34
33.	R	51	47	47	36	46
34.	R	96	93	92	75	86

* *Current exchangeable K method used by this Institute.*

** *Conventional exchangeable K method including water soluble K.*

Coefficients of correlation between the forms of K and cane yield % are shown in Table 5. The highest correlation coefficient of R = 0.6191 (or r = 0.6056) was obtained with the form of non-exchangeable K. While exchangeable K and water soluble K were not correlated with cane yield, good correlations between mineral K and total K and cane yield % have been noted.

TABLE 3. Correlations between exchangeable soil K and cane yield %

	Extractant	Multiple correlation coefficient (R)
1.	1 N NH_4OA_c, 1:10, 30 min.	0.1602
2.	1 N NH_4OA_c, 1:10, combination of 3 extracts	0.1188
3.	1 N NH_4OA_c, 1:20 10 min. (HSPA)	0.0924
4.	0.05N HCl + 0.025N H_2SO_4, 1:4, 5 min (Mehlich)	0.0187
5.	0.1N HCl, 1:20, 15 min. (Louisiana)	0.3238

The lack of correlation between water soluble and exchangeable K and yield % does not imply that these two forms of K are not important to sugarcane growth. Actually the uptake of exchangeable K by crops depends on the rate and the amount released from non-exchangeable K during cropping. Crabtree[7] noted that of the total K taken up by four potato crops, 54-74% of the K was from the non-exchangeable form on the clay loam soils, while about 75% of the K in plants grown on sandy loam soils was from exchangeable form. Hanway *et al*[9] indicated that exchangeable K is more available in coarse-textured soils than in fine-textured soils. In this study the soils consist of 10 silty clay loams, 6 sandy loam, and 9 loam to silty loam soils. Thus, both the non-exchangeable K and the exchangeable K are likely to be available to sugarcane growth. Ayres[1] also reported that non-exchangeable K contributed from 45 to 90% (average is 65%) of the total quantity of K absorbed by sugarcane crops. These all illustrated why non-exchangeable K was highly correlated with cane yield % on the 34 field experiments.

Non-exchangeable K extracted with boiling 1 N HNO_3 and correlated with cane yield

Wood and DeTurk[7] pointed out that the abilities of certain Illinois soils to maintain levels of exchangeable K under continued cropping were related to the K extractable by boiling with 1 N HNO_3. In Table 6, the recovery of non-exchangeable K was shown to increase with increasing strength of HNO_3. The coefficients of correlation between HNO_3 – extractable K and cane yield % are shown in Table 7. The ratio of non-exchangeable K extracted with 1 N HNO_3 from various soils to HNO_3 ratio was highly correlated with cane yield. Soil to HNO_3 ratio at 1:12 produced the highest correlation coefficient of R = 0.6674 (significant at 0.1% level). Increasing the concentration of HNO_3 did not improve the correlation coefficient for the soils studied. In order to improve the correlation between acid insoluble K or "readily available" non-exchangeable K and cane yield %, strong H_2SO_4 extraction as suggested by McLean and Simon[12] as well as Hunter and Pratt[10] has been evaluated.

Concentrated H_2SO_4-extractable K, highly correlated with cane yield.

Hunter and Pratt's concentrated H_2SO_4 extraction has been used to

TABLE 4. Forms of soil potassium in surface soil of field experiments in 1963/64 - 1972/73 (ppm, K)

Soil No.	Soil group	Soluble K (1)	Exch. K (2)	Non-exch. K (3)	Mineral K (4)	Total K (5)
1.	H	2	34	192	15132	15360
2.	H	4	39	253	13794	14090
3.	H	2	21	205	13882	14110
4.	H	2	32	194	14872	15100
5.	H	5	54	277	18264	18600
6.	AS_C	5	30	256	13419	13710
7.	AS_C	4	28	221	13457	13710
8.	AS_C	5	29	290	13426	13750
9.	AS_C	4	38	213	14144	14400
10.	ATL	3	17	140	21390	21550
11.	ATL	4	18	158	23170	23350
12.	ATL	8	12	214	19606	19840
13.	ATL	4	17	140	17459	17620
14.	ATL	3	15	166	24916	25100
15.	ATL	6	22	124	20228	20380
16.	ATL	2	9	184	19305	19500
17.	ATL	2	8	168	21022	21200
18.	AS_n	5	27	173	15095	15300
19.	AS_n	4	34	154	21448	21640
20.	RY	6	28	195	12221	12450
21.	RY	8	42	130	12470	12650
22.	RY	9	40	175	14256	14480
23.	RY	6	26	175	13013	13220
24.	RY	8	40	236	18966	19250
25.	RY	7	31	193	14429	14660
26.	RY	4	18	96	9782	9900
27.	RY	8	22	80	9982	10100
28.	RY	4	32	204	16960	17200
29.	RY	5	38	198	12568	12800
30.	RY	4	24	204	16568	16800
31.	RY	4	24	188	14884	15100
32.	R	8	41	109	7892	8050
33.	R	7	40	101	7752	7900
34.	R	13	80	83	8344	8520

(1) Water soluble K determined from saturation extract.

(2) Exch.K: 1 N NH_4OAc, 1:10, combination of 3 extracts − K (1)

(3) Non-exch. K: 1 N HNO_3, 1:10, boiling for 10 min. − K (1) − K (2)

(4) Mineral K: Total K − K (1) − K (2) − K (3)

(5) Total K: HF-$HClO_4$ digestion

TABLE 5. Correlations between various forms of soil potassium and cane yield %.

	Form of soil K	Linear coefficient (r)	Multiple correlation coefficient (R)
1.	Water soluble K	0.0539	0.1315
2.	Exchangeable K	0.0860	0.1069
3.	Non-exchangeable K	0.6056***	0.6191***
4.	Mineral K	0.2541	0.4383*
5.	Total K	0.2581	0.4443**

** Significant at 5% level.* *** Significant at 1% level.*
**** Significant at 0.1% level.* *No. of samples = 34.*

determine the non-exchangeable K of the tested soils. Table 8 indicated that the values of H_2SO_4 extractable K increased with increasing amount of conc. H_2SO_4 used. On the basis of soil to H_2SO_4 ratio of 1:10, the non-exchangeable K content of soils with pH $>$ 7.0 average 279 ppm which was much higher than 187 ppm k of the acid soils.

Coefficients of correlation between H_2SO_4-extractable K and cane yield % are shown in Table 9. The original procedure of Hunter and Pratt No. 1a K (1:10) was significantly correlated with cane yield %. With this test, the correlation coefficients became inferior when the amount of H_2SO_4 being used either increased or decreased in the extraction.

To simplify the procedure of Hunter and Pratt's No. 1a and improve the correlation coefficient, some modifications have been made to facilitate rapid analysis in routine tests. The following procedure was proposed to alter Hunter and Pratt's No. 1a method for non-exchangeable K tests on the soils of TSC's plantations:

Mix 2.5g soil, 15m H_2O and 5m conc. H_2SO_4, stir and stand for 30 min. Then add 30m H_2O. Filter directly without washing with 0.1 N H_2SO_4. The filtrate is analyzed for K with flame photometer.

By using modified Hunter and Pratt's No. 1a method, correlation coefficient between non-exchangeable K and cane yield % has been improved up to R = 0.7014. The correlation curve is shown in Fig. 1.

Hunter and Pratt's No. 1a procedure has been known as hot-H_2SO_4 method since it involved heat energy in soil extraction system. As measured when 10 g of soil was added with 25 ml of H_2O and 10 ml of conc. H_2SO_4, the initial temperature of suspension was quickly brought up to around 90°C. After letting it stand for 30 min, its temperature was dropped to around 36°C. Theoretically, this heat reaction would furnish a means of breakdown

TABLE 6. Soil potassium extracted with boiling 1 N HNO_3 at various soil to HNO_3 ratios (ppm, K)

Soil No.	Soil group	Soil (gm):1 N HNO_3 (ml) ratio				2N HNO_3 1:10 boiling for 10 min.	3 N HNO_3, 1:10 boiling for 10 min.
		1:6	1:8	1:10*	1:12		
1.	H	220	226	228	243	306	342
2.	H	278	276	296	314	398	440
3.	H	229	233	228	240	282	305
4.	H	222	226	228	230	280	310
5.	H	291	304	336	320	419	459
6.	AS_c	272	274	291	313	376	408
7.	AS_c	258	241	253	258	301	310
8.	AS_c	316	315	324	318	347	352
9.	AS_c	249	246	256	258	300	319
10.	ATL	144	142	160	166	227	272
11.	ATL	158	167	180	184	240	280
12.	ATL	228	224	234	242	276	290
13.	ATL	152	152	161	176	231	280
14.	ATL	186	176	184	183	215	250
15.	ATL	159	156	152	158	178	191
16.	ATL	165	173	195	182	196	220
17.	ATL	161	151	178	167	188	208
18.	AS_n	198	206	205	224	278	315
19.	AS_n	184	176	192	194	244	280
20.	RY	220	224	229	238	280	304
21.	RY	186	177	180	180	218	229
22.	RY	227	219	224	235	292	312
23.	RY	205	205	207	220	262	284
24.	RY	288	280	284	302	354	384
25.	RY	226	218	231	230	276	292
26.	RY	100	98	108	114	114	133
27.	RY	116	104	108	116	122	135
28.	RY	206	226	240	235	282	327
29.	RY	200	188	232	204	255	290
30.	RY	222	196	232	226	284	314
31.	RY	222	192	216	216	261	300
32.	R	152	145	158	158	198	220
33.	R	144	146	148	154	196	228
34.	R	180	177	176	174	214	229

* *Original procedure of Wood and DeTurk's method.*

TABLE 7. Correlation between HNO_3 -extractable K and cane yield %

	Procedure	Soil (g):extractant (ml)	Multiple correlation coefficient (R)
1.	1N HNO_3, boiling for 10 min.	1:6	0.6539***
2.	1N HNO_3, boiling for 10 min.	1:8	0.6671***
3.	1N HNO_3, boiling for 10 min.	1:10@	0.6462***
4.	1N HNO_3, boiling for 10 min.	1:12	0.6674***
5.	2N HNO_3, boiling for 10 min.	1:10	0.6434***
6.	3N HNO_3, boiling for 10 min.	1:10	0.5995***

@ *Original Wood and DeTurk's method.* *No. of samples = 34.*
*** *Significance at 0.1% level.*

of primary and secondary minerals, as well as the exchangeable K (Hunter and Pratt[10]). By diminishing the weight of soil sample and the amount of conc. H_2SO_4 being used, we found that the initial and final temperatures of the suspension were around 77°C and 34°C, respectively. Low heat reaction in soil extraction system would indicate a less amount of non-exchangeable K to be extracted. This could increase the amount of exchangeable K to be extracted since conc. H_2SO_4-extractable K actually includes the extraction of non-exchangeable and exchangeable K, as well as water soluble K. Varying the soil to H_2SO_4 ratio would result in altering the proportion of non-exchangeable and exchangeable K to be extracted and hence improve the correlation coefficient value.

CONCLUSION

Non-exchangeable soil K was found to be highly correlated with cane yield % under field conditions. It accounted for 1.14% of the total K of the soils tested. Procedure of Hunter and Pratt's No. 1a conc. H_2SO_4 method has been modified to determine non-exchangeable water soluble and exchangeable K for the soils of sugarcane fields. Significant correlation between modified Hunter and Pratt's No. 1a extractable K and cane yield % was obtained. The major advantages of this modified procedure for non-exchangeable K test have been the reduction of soil sample weight and the amount of conc. H_2SO_4 being used, the rapidity of determination and its applicability to sugarcane fields irrespective of soil types.

TABLE 8. Soil potassium extracted with concentrated H_2SO_4 at various soil to extractant ratios (ppm, K)

Soil No.	Soil Group	Hunter and Pratt No. 1a at various ml. of conc. H_2SO_4					3.6N H_2SO_4 1:10 30 min.	Modified Hunter and Pratt No. 1a 15 ml H_2O, 5 ml conc. H_2SO_4	
		1*	5	10**	15	20		5g soil	2.5g soil
1.	H	34	78	255	307	439	53	168	156
2.	H	54	153	267	489	573	82	259	256
3.	H	31	86	234	294	417	43	194	183
4.	H	39	127	385	492	563	67	271	234
5.	H	67	171	395	530	546	103	267	262
6.	AS_C	50	132	334	365	411	76	241	224
7.	AS_C	31	106	255	290	369	46	184	190
8.	AS_C	44	108	345	408	378	58	243	243
9.	AS_C	52	129	305	418	347	74	227	235
10.	ATL	36	101	171	209	231	61	147	143
11.	ATL	45	144	246	316	351	70	193	197
12.	ATL	34	108	242	255	292	51	194	189
13.	ATL	34	95	182	246	247	48	153	142
14.	ATL	21	87	188	195	187	32	131	130
15.	ATL	25	70	145	189	174	31	128	128
16.	ATL	21	85	158	179	168	39	141	148
17.	ATL	19	84	144	177	171	36	139	139
18.	AS_n	43	83	218	253	316	58	156	156
19.	AS_n	47	100	187	278	318	65	165	170
20.	RY	37	91	256	260	279	51	198	167
21.	RY	28	66	181	213	221	35	137	131
22.	RY	55	110	230	282	283	67	177	156
23.	RY	36	93	215	229	234	47	154	162
24.	RY	55	114	294	318	304	75	208	260
25.	RY	44	97	233	256	274	58	168	200
26.	RY	23	45	73	104	100	28	60	60
27.	RY	30	56	84	109	107	36	69	66
28.	RY	33	109	227	310	333	44	167	163
29.	RY	42	96	182	258	258	57	159	126
30.	RY	30	87	211	300	312	43	163	154
31.	R	35	94	211	285	292	49	154	144
32.	R	45	80	155	197	292	56	116	123
33.	R	45	82	150	188	337	51	102	102
34.	R	74	115	176	233	288	85	134	131

** Hunter and Pratt's cold H_2SO_4 method.*

*** Original procedure of Hunter and Pratt No. 1a method.*

TABLE 9. Correlations between conc. H_2SO_4-extractable K and cane yield %

	Extractant			Procedure	Multiple correlation coeff. (R)
	Soil (g)	Dist. H_2O (ml)	Conc. H_2SO_4 (ml)		
1.	10	25	1[@]	Follow Hunter & Pratt's procedure	0.2767
2.	10	25	5	"	0.5509***
3.	10	25	10	"	0.6768***
4.	10	25	15	"	0.5454**
5.	10		20	"	0.3895*
6.	5	15	5	Modified Hunter & Pratt's procedure by the authors	0.6789***
7.	2.5	15	5	"	0.7014***
8.	1	—	10ml of 3.6N H_2SO_4	Shake for 30 min, filter	0.4070*

@ *Cold H_2SO_4 method.*
Stir up, stand for 30 min and then add 30 ml of H_2O, filter, the filtrate is determined with flame photometer for K (skip to wash with 0.1N H_2SO_4).
*, **, ***: *Significance at 5%, 1%, and 0.1% levels, respectively.*
Number of samples = 34.

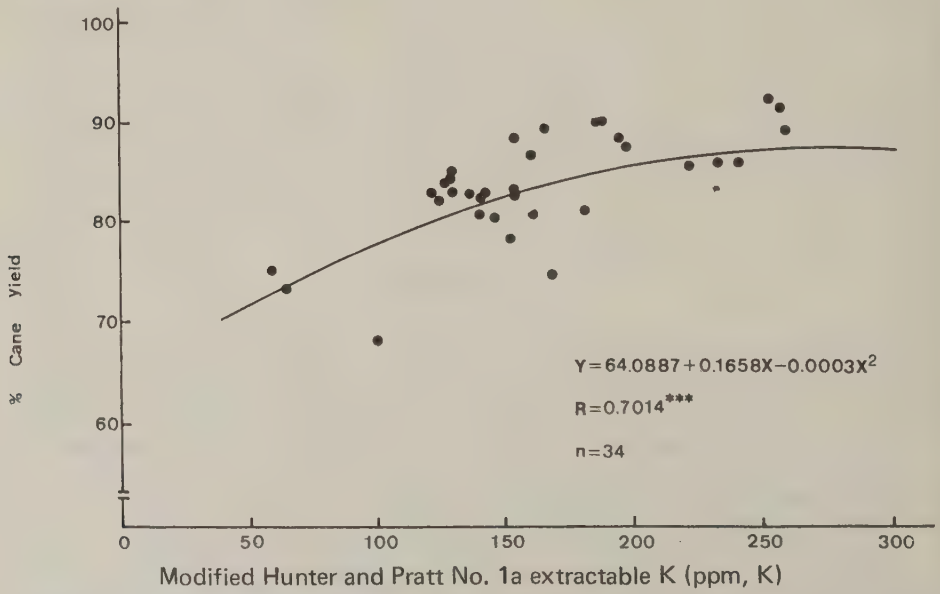

FIGURE 1. Relationship between non-exchangeable soil K and cane yield

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LA SIGNIFICANCIA DEL K NO-INTERCAMBIABLE EN RELACION AL RENDIMIENTO DE LA CAÑA DE AZUCAR

I. Fang y C. Wang

RESUMEN

De un total de 217 experimentos de campo de K llevados a cabo desde 1963/64 hasta 1972/73, 34 parcelas mostraron respuestas a aplicaciones de K a niveles significativos. Basado en estas parcelas que dieron respuestas a K, se determino que el K no-intercambiable del suelo estaba altamente correlacionadó con el rendimiento de la caña de azúcar aunque solamente promedío el 1.14% del K total analizado en el suelo.

Los autores hicieron modificaciones en el procedimiento del metodo de Hunter y Pratt No. 1 para extraer K no-intercambiable en el suelo. El K soluble en agua e intercambiable tambien son extraidos en esta prueba.

El coeficiente de correlación (R) entre este método modificado de Hunter y Pratt No. 1 para extraer K y el rendimiento de caña % bajo condición de campo fue igual a 0.7014, que es significativo al 1% de probabilidad. El procedimiento modificado para extraer K no-intercambiable del suelo fué superior al método original de Hunter y Pratt en algunos aspectos tal como la reducción del peso de la muestra de suelo y la concentración del ácido H_2SO_4 utilizado, facilidad de trabajo analitico y aplicabilidad a campos cañeros sin consideración del tipo de suelo.

El procedimiento para determinar el K no-intercambiable en

el suelo según fué modificado por los autores se puede describir de la siguiente manera:

Coloque 2.5g de suelo en un vaso picudo para análisis de 100 ml, agregue 15 ml de H_2O, luego se la agrega poco a poco 5 ml de H_2SO_4 concentrado y se agita. Se deja en reposo por 30 minutos, se agregan 30 ml de H_2O y se filtra directamente. El filtrado se determina mediante un fotometro de llama.

WEEDS OF MECHANIZED SUGARCANE FIELDS OF JAVA: THEIR ECONOMIC IMPORTANCE AND CONTROL

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ABSTRACT

Weed species observation, weed competition study and herbicide screening trials in mechanized cane fields were conducted in three sugar estates in Java, from July, 1975 until May, 1978.

Weed species shifts occurred and more *Cyperus rotundus, Amaranthus spinosus. Trianthema portulacastrum. Euphorbia heterophylla* and *Portulaca oleraceae* grew in the mechanized fields. These weed flora exerted less competition to the sugarcane, and about 9.5 to 11.1% less cane yield losses occurred in mechanized compared to the Reynoso field. Herbicide mixtures namely; Asulox (asulam) + Actril DS (ioxynil); Destun (Perfluedone), Gesapax (ametryre), gesaprim (atrazure), Erbotan (thiazfluron), Karmex (diuron), Sencor (metribuzin), Sirmate (dichlormate), Ravage (buthidozole) Devrino (napropamide), and Totacol (paraquat and diuron) plus U 46 Fluid (2, 4-D amine); and a single herbicide Goal (oxyfluorfen), were tested in two rates and were sprayed one week after planting the cane. Mixtures of Gesapax at 2.4 kg/ha, Karmex at 1.2 and 2.4 kg/ha, Sencor at 1.4 kg/ha, Ravage at 1.5 kg/ha and Totacol at 2.4 kg/ha plus 2,4-D at 1.4 kg a.e./ha and Goal at 1.6 kg/ha, could sufficiently check the weed growth for about two months after cane planting. Except for *Cyperus rotundus,* all weed species found in the plots were satisfactorily controlled by the above herbicides.

No harmful effects of the herbicides toward the cane shoots were shown, but Goal causes yellow discoloration and necrotic spots to cane foliage though this did not affect its further growth.

INTRODUCTION

Since the pre-war period, sugarcane in Java was mostly grown in rotation with rice on flat-alluvial-irrigated rice fields. Due to the highly clay content of the soil, while lands are inundated for the greater part of the year for rice growing, a distinct cane cultivation method known as "Reynoso system" has

been used. Basically this method differs from other common methods in two respects: it has very intensive drainage ditches, and only a small part of the soil (in the cane furrows) is worked out to fine tilt. To prepare cane fields according to this method, a considerable amount of manual labor is needed.

Temporary labor shortage during the planting or harvesting period of other food crops (rice, soybean, corn), competitive wages for jobs of non agricultural sectors and definite optimum cane planting period (June-July), necessitate finding other cultivation methods which could better overcome the labor shortage problems. The method of soil preparation, by using disc or mouldboard plow followed later by harrowing, could hasten the soil preparation and reduce the number of laborers required.

Despite of the above advantage, the method creates new problems, the most outstanding of which is the profusely and vigorously growing *Cyperus rotundus* L. immediately after the cane planting. This weed species which seldom grows in abundance in the old "Reynoso" system (Kuntohartono and Darsono Ariadi[1]) becomes a dominant weed in the mechanized cane fields. This species could grow more than 25 cm high during the first three weeks after cane planting and causes difficulties in cane maintenance such as fertilization, replanting dead seed pieces and hand weeding.

The present study was conducted specifically to: (1) observe the weed species shifts caused by the changing soil preparation method, (2) determine the economic importance of the weed species which grew in association with canes in both Reynoso and mechanized soil preparation methods and (3) select the best herbicide or herbicides mixtures for controlling weed species which were prevalent in the mechanized cane fields in Java.

MATERIALS AND METHODS

The trials were mostly carried out in alluvial clayloam to loamy-clay textured soil, at Jatiroto and Wringinanom Sugar Estates. Soil preparations consisted of disc plowing and harrowing, followed by furrowing and digging drainage ditches manually. Row distance and length of furrows varied from 1.25 to 1.45 m, and 12.5 to 25 m, respectively.

Determination of weed species was conducted six weeks after cane planting in fields with "Reynoso" and "Semi-mechanized" systems. Both fields were placed side by side and planted approximately at the same time. The weeds were determined and assessed visually by using the "abundance ratings" as described by Rochecouste[4], and were conducted in the nurseries as well as milling cane fields in November, 1976 and July, 1978, respectively.

Weed competition trials were installed in both fields to determine the economic importance of weeds. Plots of 5.0 x 8.0 m were planted with Ps 30 variety and handweeded according to the treatments, i.e., weeding at 3, 6, 9, 12 weeks after planting, weeding at 2 and 4 weeks; weeding at 6 and 8

weeks; weeding at 10 and 12 weeks and no weeding at all until harvest. At harvest time (12 months) the cane stalk were weighed. The trials were carried out from June,1977 until July,1978.

Screening trials for selecting the best herbicide or herbicide mixtures were conducted in the milling cane fields of Jatiroto and Pesantren SE, from July, 1975 until May, 1978. There were six experiments, namely experiment I and II in July, 1975/76 at Jatiroto, experiment III and IV at Jatiroto and Pesantren in 1976/77, and finally experiment V and VI at Jatiroto in 1977/78. Fifteen herbicides and their mixtures at two dosage levels were evaluated for their over-all weed control effects as well as their specific weed species effects. Nearly all herbicide mixtures contained 2, 4-D amine (U 46 Fluid), to increase *Cyperus rotundus* control. They were sprayed in 400% water per hectare, with semi-automatic knapsack sprayers and spraying system 8004 fanjets, and applied at one to two weeks after cane planting. The soil texture, moisture status and climatic conditions at spraying time and several days afterwards were recorded.

All plots were 4.5 m x 25 m each (Experiment 1 and II) 6.0 m x 10 m (Experiment III and IV) and 4.5 m x 12 m (Experiment V and VI) in size, and were replicated four times (except Experiment V with two replications) with randomized block design. In all experiments, Ps 41 or NCo 376 variety were used.

Over-all weed control performance data were based on the percentage of weed (regrowth) coverage, one and two months after cane planting, while the specific weed species control data were based on the visual abundance ratings of the dominant weed species which grew after herbicides application. The percentage of weed coverage data were subjected to Fisher and Duncan Multiple Range tests.

Cane foliage toxicity symptoms were visually rated at approximately one and two months after herbicide application Cane shoots and their heights were counted and measured at the cane age of three and six months, and the data were subjected to Fisher test.

RESULTS

Weed species observation

Changing the method of soil preparation causes a dramatic shift in weed species and their order of abundance. Nearly all grass species which were dominant in the Reynoso fields, were eliminated in kinds as well as abundance in the mechanized fields, except for *Eleusine indica* in the milling cane fields of Jatiroto. As for sedges, *Cyperus rotundus* which belongs to common weeds found in Reynoso fields, became the most abundant species in mechanized fields, but not, however, in the case of the other sedge: *Fimbristylis miliaceae.* Some broadleaf weed species were eliminated in mechanized

TABLE 1. Weed species composition at six weeks after planting, of cane fields cultivated according to Reynoso (R) and Mechanization (M).

Weed species	Cane fields	Milling cane				Nursery	
	Location	Wringinanom		Jatiroto		Jatiroto	
	Cultivation system	R	M	R	M	R	M
Grasses							
Cynodon dactylon Pers.		2[1)]	1	3	–	3	–
Echinochloa colonum L.		4	1	4	–	7	1
Eleusine indica Gaertn.		–	–	–	2	–	–
Leptochloa chinensis Nees.		–	–	4	–	–	–
Panicum reptans L.		2	3	3	–	2	1
Polytrias amaura Hack		–	–	–	–	5	1
Sedges							
Cyperus rotundus L.		1	4	5	7	2	5
Fimbristylis miliaceae Vahl.		–	–	4	–	–	
Broad leaves							
Ageratum conyzoides L.		–	–	3	1	–	–
Amaranthus spinosus L.		1	2	–	2	2	1
Commelina benghalensis L.		–	–	2	–	–	–
Eclipta prostrata (L) L.		–	–	2	–	4	–
Euphoribia hirta L.		–	–	–	1	–	–
Euphorbia heterophylla L.		–	–	–	–	–	2
Ipomoea triloba L.		1	1	4	4	–	1
Polanisia chelidonii DC.		2	2	–	–	–	–
Physalis minima L.		1	1	–	–	–	–
Phyllanthus niruri L.		–	–	3	2	2	–
Portulaca oleraceae L.		–	–	–	8	–	–
Trianthema portulacastrum L.		–	3	–	–	–	–

1) *Mean visual rating of weed species abundance ratings according to Rochecouste*[4]*; 1 = very rare and, 8 = very abundant.*

fields, but some species namely *Amaranthus spinosus, Euphorbia heterophylla, Portulaca oleraceae* and *Trianthema portulacastrum* became more abundant (Table 1). Except for *Cyperus rotundus,* these weed populations were presumably less competitive to the cane plants, because weeds belonging to the

same family as cane have been greatly reduced.

Economic importance of weed vegetation

To test the above presumption, a comparison of the magnitude of cane yield reduction due to the different weed compositions and their competition to cane growth, has been carried out in both fields. Except for one treatment (weed competition at the first and third month), the yield losses in the Reynoso field were 9.5 to 11.1% higher than in the mechanized field (Table 2). These trial results proved that weed vegetation in a mechanized fields was less harmful than weeds in a Reynoso field.

TABLE 2. Influence of weed competition period toward milling cane yield on Reynoso and Mechanized cane fields at Wringinanom (average of four replications)

Treatments	Reynoso		Mechanization	
	Yield	%	Yield	%
Standard weeding practice (hand weeded at 3, 6, 9, 12 weeks after planting)	1424.2	100	1165.4	100
Weed competition at 2nd and 3rd month (hand weeded at 2nd and 4 weeks)	1372.9	96.4	1252.3	107.5
Weed competition at 1st and 3rd month (hand weeded at 6 and 8 weeks)	1538.6	108.0	1293.0	110.9
Weed competition at 1st and 2nd month (hand weeded at 10 and 12 weeks)	990.5	69.5	922.6	79.2
No weed control (no handweeding until harvest)	970.5	68.1	904.2	77.6

Apparently the critical cane growth period toward weed competition remained the same in both fields. Cane was most susceptible to weed competition during the first and second months after planting. This period coincided with the establishment of young cane shoots and the beginning of the tillering phase. These results were in accordance with the experimental results conducted by Singh and Verma[5] and Millholon[3]. From the trial results, one can deduce that weed control should be carried out during the first and second month after planting, if normal cane yield should be obtained.

The higher cane yield in Reynoso compared to mechanized field as shown in Table 2, was caused by better germination of the cane cuttings in the former. The source of the difference was unknown to us.

Overall weed control performances

The chemical names and their active ingredients or acid equivalent of the herbicides evaluated are shown in the Appendix . Percentage of weed coverage of all treatments at approximately one and two months after planting are shown in Tables 3 and 4, respectively. The figures obtained are very irregular, and the overall weed control ability varies greatly from one experiment to the other, indicating the big environmental factors interaction toward the weed control performances of each herbicide treatment. In this particular case, the selected treatments should have stable performances in most experiments, beside their outstanding weed control ability in a specific individual trial. Hence, the procedure of selection is manipulating the statistical grouping and utilizing the highest tolerable weed coverage percentage (in this case 15%, as tentative arbitrary figure).

By utilizing the above procedures the selected treatments at one month after planting are as follows: Gesapax + 2,4-D at rates of (1.2 – 2.4 + 1.4) kg/ha, Erbotan + 2,4-D at rates 1.2 – 2.4 + 2.4) kg/ha, Karmex + 2,4-D (1.2 – 2.4 + 1.4) kg/ha, Sencor + 2,4-D (1.4 + 1.4) kg/ha, Sirmate + 2,4-D (0.9 + 1.4) kg/ha, Ravage + 2,4-D (0.75 – 1.5 + 1.4) kg/ha and Totacol + 2,4-D (2.4 + 1.4) kg/ha. These treatments belong to the best statistical groups (according to Duncan test) and are lower than the 15% weed coverage in experiment I, II, III and IV. In the last two experiments, the weed control performances of these treatments were less satisfactory, owing to the very dry season during the 1977 planting period (Table 3). Presumably the herbicides' activities in the soil were somewhat affected by insufficient soil moisture.

The high weed control performances in the first month after planting are greatly diminished in the following month. The best and selected treatments at two months after planting are: Gesapax + 2,4-D at (2.4 + 1.4) kg/ha, Karmex + 2,4-D at (1.2 – 2.4 + 1.4) kg/ha, Sencor + 2,4-D (0.7 – 1.4 + 1.4) kg/ha, Goal at 0.8 and 1.6 kg/ha, Ravage + 2,4-D (1.5 + 1.4) kg/ha and Totacol + 2,4-D (1.2 – 2.4 + 1.4) kg/ha. There are some treatments which show better performance in the second month i.e., Sencor + 2,4-D (0.7 + 1.4) kg/ha, Goal at 0.8 and 1.6 kg/ha and Totacol + 1.4-D at (1.2 + 1.4) kg/ha. Judging from the previous weed competition trial (Table 2) and the weed control performance stability in both months, the best and selected treatment for the whole series of experiments are: Gesapax + 2,4-D (2.4 + 1.4) kg/ha, Karmex + 2,4-D (1.2 – 2.4 + 1.4) kg/ha, Sencor + 2,4-D (1.4 + 1.4) kg/ha and Totacol + 1,4-D at (2.4 + 1.4) kg/ha.

Specific weed species control

The overall weed control performance of herbicide (percentage of weed coverage) usually corresponds with their ability to affect the growth of one or more weed species which dominated the weed vegetation. To show the above relationship as well as studying the specific weed species control of the herbicides, visual abundance rating of regrowing weed species at two occasions after application were carried out, and the better weed control

TABLE 3. Percentage of weed coverage of plots, approximately one month after planting (except for Experiment V, all figures are the average of 4 replications)

Herbicides	kg(1)/ha ai or ae	1975/76		1976/77		1977/78	
		Exp. I	Exp. II	Exp. III.	Exp. IV	Exp. V	Exp. VI
Asulox + Actril DS	1.6 + 1.4	$16.3^{b\ 1)}$	4.5^{e}	–	–	$12.0^{2)}$	–
	2.4 + 1.4	–	–	6.8^{hij}	3.8^{kim}	18.0	–
Destun + U 46 Fluid	1.5 + 1.4	17.5^{b}	3.8^{e}	13.5^{h}	10.3^{k}	16.0	–
	3.0 + 1.4	16.3^{b}	5.0^{e}	13.5^{h}	7.5^{kim}	9.5	–
Gesapax + U 46 Fluid	1.2 + 1.4	12.0^{bc}	0.0^{f}	5.5^{hij}	4.8^{lmm}	16.5	–
	2.4 + 1.4	17.5^{b}	1.0^{e}	2.8^{j}	2.3^{mn}	12.0	–
Gesaprim + U 46 Fluid	1.2 + 1.4	15.0^{bc}	4.0^{e}	–	–	18.0	–
	2.4 + 1.4	15.0^{bc}	2.0^{e}	–	–	18.0	–
Erbotan + U 46 Fluid	1.2 + 1.4	13.8^{bc}	1.0^{e}	7.3^{hij}	7.0^{ki}	19.0	12.0
	2.4 + 1.4	12.5^{bc}	1.0^{e}	7.8^{hij}	2.5^{mn}	18.0	16.3
Karmex + U 46 Fluid	1.2 + 1.4	13.8^{bc}	0.0^{f}	9.8^{hij}	4.0^{lmn}	20.5	14.0
	2.4 + 1.4	11.3^{bc}	0.0^{f}	5.0^{hij}	3.3^{lmn}	11.0	9.8
Sencor + U 46 Fluid	0.7 + 1.4	17.5^{b}	1.8^{e}	6.3^{hij}	4.0^{lmn}	22.5	–
	1.4 + 1.4	15.0^{bc}	0.0^{f}	4.0^{ij}	–	41.0	–
Sirmate + U 46 Fluid	0.9 + 1.4	13.8^{bc}	0.0^{f}	11.3^{hi}	–	10.0	–
	1.8 + 1.4	15.8^{b}	1.0^{e}	8.8^{hij}	–	13.0	–
Goal	0.8	–	–	10.8^{hi}	3.0^{lmn}	28.0	–
	1.6	–	–	5.0^{hij}	3.8^{lmn}	25.0	–
Ravage + U 46 Fluid	0.75 + 1.4	15.0^{bc}	1.3^{e}	6.3^{hij}	2.3	12.5	17.5
	1.5 + 1.4	17.5^{bc}	1.0^{e}	30.0^{hj}	3.0^{lmn}	12.5	11.8
Devrinol + U 46 Fluid	1.0 + 1.4	–	–	14.8^{h}	–	19.0	–
	2.0 + 1.4	–	–	7.5^{hij}	–	13.0	–
Totacol + U 46 Fluid	1.2 + 1.4	–	–	5.3^{hij}	–	15.0	8.8
	2.4 + 1.4	–	–	3.5^{ij}	1.5^{n}	12.5	11.5
Handweeded check		67.5^{a}	19.5^{d}	65.0^{g}	10.3^{k}	25.0	30.8
Rainfall accumulation in mm		0.0	0.0	0.0	7	0.0	0.0

1) Figures followed by same letters are not significantly different at 5% probability level of Duncan Multiple Range test.

2) Columns without letters imply that the figures are not significantly different (P.05)

TABLE 4. Percentage of weed coverage of plots, approximately two months after

Herbicides	Kg(1)/ha ai or ae	1975/76		1976/77		1977/78	
		Exp. I	Exp. II	Exp. III	Exp. IV	Exp. V	Exp. VI
Asulox + Actril DS	1.6 + 1.4	35.0^{b}	27.5^{hij}	–	–	10.5	–
	2.4 + 1.4	–	–	6.5^{q-v}	7.0	17.5	–
Destun + U 46 Fluid	1.5 + 1.4	25.0^{c-g}	33.8^{h}	14.3^{pq}	7.3	14.5	–
	3.0 + 1.4	20.8^{d-g}	31.3^{hi}	12.3^{qrs}	4.0	11.5	–
Desapax + U 46 Fluid	1.2 + 1.4	25.8^{c-f}	23.8^{h-k}	6.0^{q-v}	6.8	12.5	–
	2.4 + 1.4	23.8^{c-g}	25.0^{h-l}	4.0^{tuv}	6.3	10.5	–
Gescprim + U 46 Fluid	1.2 + 1.4	21.0^{d-g}	26.3^{h-k}	–	–	13.0	–
	2.4 + 1.4	28.8^{b-e}	26.3^{h-k}	–	–	15.0	–
Erbotan + U 46 Fluid	1.2 + 1.4	28.8^{b-e}	30.0^{hi}	10.9^{q-u}	6.3	10.0	10.5
	2.4 + 1.4	26.3^{c-f}	22.0^{j-n}	5.8^{q-v}	4.3	11.0	13.3
Karmex + U 46 Fluid	1.2 + 1.4	23.8^{c-g}	22.5^{i-m}	6.0^{q-v}	5.8	14.0	11.8
	2.4 + 1.4	22.5^{c-g}	19.0^{k-o}	5.0^{r-v}	6.5	9.0	12.5
Sencor + U 46 Fluid	0.7 + 1.4	22.5^{c-g}	17.0^{l-o}	6.8^{q-v}	6.0	13.0	–
	1.4 + 1.4	23.8^{c-g}	19.5^{j-n}	6.0^{q-v}	4.0	14.0	–
Sirmate + U 46 Fluid	0.9 + 1.4	19.0^{fg}	23.8^{h-l}	11.3^{q-t}	–	7.5	–
	1.8 + 1.4	20.0^{efg}	20.0^{j-n}	7.5^{q-v}	–	11.0	–
Goal	0.8	–	–	4.8^{n-v}	7.8	12.0	–
	1.6	–	–	3.8^{u-v}	5.3	13.0	–
Ravage + U 46 Fluid	0.75 + 1.4	25.0^{c-g}	23.3^{h-m}	8.0^{l-v}	4.8	11.5	16.5
	1.5 + 1.4	30.0^{fg}	23.3^{h-m}	3.5^{r}	5.3	11.0	12.8
Devrinol + U 46 Fluid	1.0 + 1.4	–	–	15.0^{pq}	–	18.0	–
	2.0 + 1.4	–	–	13.5^{qr}	–	10.0	–
Totacol + U 46 Fluid	1.2 + 1.4	–	–	4.3^{s-v}	–	10.5	11.0
	2.4 + 1.4	–	–	4.0^{tuv}	6.8	11.5	14.0
Handweeded, check		67.5^{a}	14.5^{ns}	25.8^{p}	8.3	12.0	13.0
Rainfall accumulation in mm		0.0	0.0	0.0	7	79	79

TABLE 5. Mean visual abundance ratings of weed species found in Experiment I.

Herbicides	Kg(1)/ha ai or ae	*C. rotundus*			*Digitaria* spp.			*P. reptans*			*A. spinosus*			*I. triloba*		
		7*)	43	73	7	43	73	7	43	73	7	43	73	7	43	73
Asulux + Actril DS	1.6 + 1.4	4	5	3	0	1	1	0	1	1	0	3	2	1	1	1
Destun + U 46 Fluid	1.5 + 1.4	4	5	2	0	2	2	0	3	1	0	3	0	1	0	1
	3.0 + 1.4	4	5	1	0	1	2	0	3	2	0	1	1	1	0	1
Gesapax + U 46 Fluid	1.2 + 1.4	4	5	2	0	0	1	0	1	1	0	0	1	1	1	1
	2.4 + 1.4	4	5	2	0	0	2	0	2	1	0	2	0	1	0	1
Gesaprim + U 46 Fluid	1.2 + 1.4	4	4	2	0	1	3	0	2	1	0	0	0	1	0	0
	2.4 + 1.4	4	5	2	0	0	2	0	3	1	0	1	0	1	1	1
Erbotan + U 46 Fluid	1.2 + 1.4	4	5	2	0	0	2	0	2	1	0	1	1	1	0	1
	2.4 + 1.4	4	6	3	0	1	2	0	1	1	0	0	0	1	1	0
Karmex + U 46 Fluid	1.2 + 1.4	4	5	2	0	1	1	0	1	1	0	0	0	1	1	0
	2.4 + 1.4	4	4	3	0	1	1	0	2	0	0	1	0	1	2	0
Sencor + U 46 Fluid	0.7 + 1.4	4	5	3	0	0	1	0	1	0	0	1	0	1	1	1
	1.4 + 1.4	4	5	2	0	0	1	0	0	0	0	3	0	1	1	1
Sirmate + U 46 Fluid	0.9 + 1.4	4	5	1	0	2	2	0	2	1	0	2	0	1	1	0
	1.8 + 1.4	4	5	1	0	1	2	0	0	1	0	1	0	1	2	1
Ravage + U 46 Fluid	0.75 + 1.4	4	5	3	0	1	2	0	1	0	0	1	0	1	1	1
	1.5 + 1.4	4	6	3	0	1	1	0	1	1	0	1	1	1	0	0
Handweeded check		4	7	2	0	3	3	0	3	2	0	3	2	1	2	2

*) *Number of days after planting: first observation (7 days after planting) carried out before the herbicide applications.*

TABLE 6. Mean visual abundance ratings of weed species found in Experiment III and V

Herbicides	Kg(1)/ha ai or ae	Experiment III									Experiment IV								
		Digitaria spp.			C. rotundus			I. Triloba			Digitaria spp.			P. amaura			C. rotundus			I. Triloba		
		7	29	59	7	29	59	7	29	59	7	28	56	7	28	56	7	28	56	7	28	56
Asulux + Actril DS	1.6 + 1.4	–	–	–	–	–	–	–	–	–	1	0	0	2	0	0	3	6	4	1	1	1
	2.4 + 1.4	0	1	3	4	3	4	4	0	0	1	0	0	2	0	0	3	8	5	1	1	1
Destun + U 46 Fluid	1.5 + 1.4	0	3	6	4	3	2	4	0	0	1	0	0	2	1	0	3	8	5	1	1	2
	3.0 + 1.4	0	5	6	4	3	3	4	0	0	1	0	0	2	1	0	3	4	5	1	1	1
Gesapax + U 46 Fluid	1.2 + 1.4	0	3	4	4	2	2	4	0	0	1	0	0	2	0	0	3	6	5	1	0	1
	2.4 + 1.4	0	0	1	4	1	3	4	0	0	1	0	0	2	0	0	3	6	4	1	0	1
Gesaprim + U 46 Fluid	1.2 + 1.4	–	–	–	–	–	–	–	–	–	1	0	0	2	0	0	3	6	5	1	1	1
	2.4 + 1.4	–	–	–	–	–	–	–	–	–	1	0	0	2	0	0	3	6	5	1	0	1
Erbotan + U 46 Fluid	1.2 + 1.4	0	2	5	4	2	5	4	0	0	1	0	0	2	2	0	3	7	4	1	1	1
	2.4 + 1.4	0	2	2	4	3	3	4	0	0	1	0	0	2	0	0	3	5	5	1	0	0
Karmex + U 46 Fluid	1.2 + 1.4	0	3	2	4	4	3	4	0	0	1	0	0	2	0	0	3	8	5	1	1	0
	2.4 + 1.4	0	1	3	4	2	4	4	0	0	1	0	0	2	0	0	3	4	4	1	0	1
Sencor + U 46 Fluid	0.7 + 1.4	0	2	2	4	2	3	4	0	0	1	0	0	2	0	0	3	8	6	1	1	0
	1.4 + 1.4	0	1	3	4	2	3	4	0	0	1	0	0	2	0	0	3	8	6	1	0	0
Sirmate + U 46 Fluid	0.9 + 1.4	0	4	5	4	2	4	4	0	0	1	0	0	2	1	0	3	4	3	1	1	1
	1.8 + 1.4	0	3	4	4	3	3	4	0	0	1	0	0	2	0	0	3	6	4	1	0	0
Goal	0.8	0	3	3	4	3	3	4	0	0	1	0	0	2	0	0	3	8	5	1	1	0
	1.6	0	3	1	4	2	2	4	0	0	1	0	0	2	0	0	3	8	5	1	1	1
Ravage + U 46 Fluid	0.75 + 1.4	0	2	2	4	3	4	4	0	0	1	0	0	2	1	0	3	6	5	1	0	0
	1.5 + 1.4	0	2	2	4	1	2	4	0	0	1	0	0	2	0	0	3	7	4	1	0	2
Devrinol + U 46 Fluid	1.0 + 1.4	0	5	6	4	2	3	4	0	0	1	0	0	2	0	0	3	8	6	1	0	0
	2.0 + 1.4	0	2	7	4	3	3	4	0	2	1	1	0	2	1	0	3	6	4	1	1	1
Totacol + U 46 Fluid	1.2 + 1.4	0	2	2	4	2	3	4	0	0	1	0	0	2	1	0	3	7	4	1	0	1
	2.4 + 1.4	0	0	1	4	1	3	4	1	0	1	0	0	2	0	0	3	6	5	1	1	2
Hand weeded check		0	0	4	4	4	3	4	5	5	1	0	0	2	0	0	3	7	4	1	2	1

performances of the trial (experiment I, III and V) were selected and illustrated in Table 5 and 6.

Cyperus rotundus

All treatments in experiment I and V failed to prevent the germination and regrowth of this species; whereas in experiment III (Table 6), Gesapax + 2,4-D and Ravage and Totacol + U46 Fluid at high rate could somewhat hamper the growth of this species at one month after planting. In experiment I and III the abundance and the growth vigor of the weed reduces with time, but this is not the case in experiment V. in the last experiment, the highest abundance ratings were at 28 days after planting.

Digitaria spp.

There were species that were not encountered in the observation before (Table 1), but appeared in higher frequency in experiment I and particularly experiment III. Some treatments in experiment I, namely; Asulox + Actril DS and Gesapax + 2,4-D at low rates, both dosage levels of Karmex and Sencor plus U 46 Fluid and Ravage + 2,4-D at high rate satisfactorily prevent the re-growth of the weed. In experiment III, only Gesapax and Totacol + 2,4-D at high rates sufficiently checked the weed regrowth, whereas in experiment V, all treatments were controlling the weed effectively.

Panicum reptans

The one of several grass species that survived the disturbances of mechanized soil preparation (Table 1) and appeared in low abundance in experiment I, Asulox + Actril DS and Gesapax + 2,4-D at low rates, Erbotan + 2,4-D high rate, Karmex + 2,4-D in both rates satisfactorily controlled this weed. The highest weed ratings was in 43 days after planting.

Polyrias amaura

This weed was prevalent in experiment V, and most treatments satisfactorily controlled this weed (Table 6).

Amaranthus spinosus

This weed was prevalent in experiment I, except for some treatments i.e. Asulox + Actril DS and Destun + 2,4-D at low rates, Gesapax and Sencor + 2,4-D at high rates and Sirmate + 2,4-D at low rate, all other treatments controlled the weed sufficiently (Table 5).

Ipomea triloba

A common broadleaf weed which grew in Reynoso and mechanized fields, it was found in all locations and at low densities in experiment and at higher density in experiment III. Almost all treatments, except

Karmex and Sirmate + 2,4-D at low rates (Experiment I), Destun at low and Ravage + U 46 Fluid at high rate, were able to suppress the weed satisfactorily.

Examining the relationship of the above data and the weed cover percentages of the best and selected treatments, it can be seen that: Gesapax + 2,4-D at high rate, Karmex + 2, 4-D at low rate, Sencor + 2, 4-D at high rate, Ravage and Totacol + 2, 4-D at high rates, provide good weed species control to grasses (*Digitaria* spp., *P. reptans* and *P. amaura*) and broadleaf weeds (*A. spinosus* and *I. triloba*). However no relationship existed between weed cover percentage and *Cyperus rotundus* control data, due to the fact that there is no single treatment tested which is good enough to kill this weed. There are no relationships whatsoever between those two data on Karmex + 2, 4-D and Goal at high rates.

APPENDIX. Herbicides used in the screening trials

Common name	Trade/code name	Manufacturer	Formulation
Asulam	Asulox	Rhone-Poulenc	40% w/v (L)
Ioxynil/2.4 Dester	Actril DS	—do—	700 gr/l ae (L)
Perfluidone	Destun	3 M	50% (L)
Ametryn	Gesapax	Ciba-Geigy	80% wp
Atrazine	Gesaprim	—do—	—do—
Diazol urea	Erbotan	—do—	—do—
Diuron	Karmex	Du Pont	—do—
Metribuzin	Sencor	Bayer	70% wp
	Sirmate	Union Carbide	45% EC (L)
Oxyfluorfen	Goal	Rhom-Hass	40% EC (L)
Buthidazole	Ravage	Velsicol	75% wp
Napropamide	Devrinol	Stauffer	50% wp
Diuron/paraquat	Totacol	I.C.I.	30%+10% w/v (L)
2.4 D amine	U 46 Fluid	BASF	720 gr/l ae (L)

wp = wettable powder *EC = Emulsifiable concentrate*

ae = acid equivalent *(L) = liquid*

Herbicide effects on sugarcane growth

Only Goal herbicide at both rates showed yellow discoloration with necrotic spots spread evenly in the leaf blades, at two to four weeks after its application. These symptoms disappeared one month later and the cane apparently recovered from the herbicide effects. All herbicide treatments evaluated resulted in normal cane growth and no harmful effects were observed due to their application to the number and height of the cane shoots at three and

six months of age.

DISCUSSION

The weak relationship between the percentage of overall weed coverage (Table 3 and 4) and weed species (especially *Cyperus rotundus*) abundance ratings (Table 5 and 6), were believed to be caused by the form and habit of growth of the species. Weeds with dense foliage and creeping habit will have high percentage of coverage, while thin erect leaves such as *C. rotundus* leaves will get a low percentage of coverage. Furthermore, the numerical values of the weed "abundance ratings" (Rochecouste[4]) of regenerating weeds could not always be related to the weed coverage data.

Efforts to control *C. rotundus* effectively were not obtained in these trials, even though 2, 4-D amine were added to most of the herbicides. Considering the high abundance rates of this weed in each sprayed plots, it can be seen that cane still grew normally (compared to handweeded check plots), indicating that *C. rotundus* did not affect the cane growth seriously. Thus the objective of its control should be aimed at the ease of manual crop maintenance, such as fertilization, replanting, interrow cultivation and filling in the furrows and others.

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MALEZAS EN CAMPOS DE CAÑA MECANIZADOS EN JAVA, SU IMPORTANCIA ECONOMICAS Y RESULTADOS DE ENSAYOS DE CONTROL

T. Kuntohartono y P. Tarmani

RESUMEN

Desde Julio, 1975 hasta Mayo, 1978 se examinaron las especies de malezas, se hicieron estudios de competencia de malezas y se realizaron pruebas de herbicidas en campos de caña mecanizados en tres plantaciones en Java.

Hubieron cambios en las especies de malezas encontrándose más *Cyperus rotundus, Amaranthus spinosus, Trianthema portulacastrum, Euphorbia heterophylla* y *Portulaca oleraceae* creciendo en campos mecanizados. Estas especies de malezas ejercieron menor competencia sobre la caña de azucar, y alrededor de 9.5 a 11.1 porciento menos perdidas en rendimiento de caña comparado al campo Reynoso. Mezclas de herbicidas señaladamente; Asulox + Actril DS; Destun, Gesapax, Gesaprim, Erbotan, Karmex, Sencor, Sirmate, Ravage, Devrinol y Totacol todos más U 46 Fluid (2, 4-D Amina); y un herbicida solo Goal, se probaron a dos dósis y se aplicaron una semana despúes de ser sembrada la caña. Mezclas de Gesapax a 2.4 kg/ha, Karmex a 1.2 y 2.4 kg/ha, Sencor a 1.4 kg/ha, Ravage a 1.5 kg/ha y Totacol a 2.4 kg/ha mas U 46 Fluid a 1.4 kg i.a./ha y Goal a 1.6 kg/ha, pudieron controlar suficientemente el crecimiento de malezas por más ó menos dos semanas despúes de la siembra. Con excepción de *Cyperus rotundus,* todas las especies de malezas encontradas en las parcelas experimentales fueron controladas satisfactoriamente por los herbicides mencionados arriba.

No se observó ningun efecto daniño de los herbicides hacia la caña, aunque Goal produjo un amarillamiento y manchas necróticas en el follaje de la caña que no afectó su subsiguiente desarrollo.

SUGARCANE SPACING I. HISTORICAL AND THEORETICAL ASPECTS

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ABSTRACT

Row spacing has apparently evolved from close to wide spacings as an accommodation to mechanization. A review of experiments in over 80 years showed that decreased spacings resulted in increased yields of cane. More pronounced responses have been reported in temperate and sub-tropical sugarcane areas, but significant yield increases with closer spacings have been reported from the tropics. For a given area, as interplant distance decreases arithmetically, the plant population increases exponentially. Even though plant weight and the number of stalks per plant decrease with decreased spacing, the effect of population is such that the theoretical yield also increases exponentially with closer spacing.

DISCUSSION

In established natural stands of wild canes *(Saccharum spontaneum),* culms of small clones may grow as close as 2 cm and culms of larger clones may be only 5 cm apart. Cultivated sugarcane varies in interrow spacing; rows of *S. barberi* may be 30 cm apart and rows of the inter-specific hybrids in commercial production vary in distance from 60 to 240 cm (Table 1). In the past, interrow distances probably were less than those used at present. Spacings of 60 cm in 1819, 79 cm in 1833 and 91 cm in 1848 were described for Louisiana (Fleishmanm[7], Silliman[18] and Spalding[19]), and 91 cm for Spain (Spalding[19]).

In an extensive review of interrow spacing studies before 1930, Webster[22] reported that rows in India were as close as 46 cm. while in Argentina and Hawaii, rows were as wide as 244 cm with varieties of *S. officinarum.* After reviewing 214 comparisons in 6 countries, Webster concluded that, in the majority of cases, greater yields were obtained when cane was planted on close rows, and he cited the conclusion of Cross in 1919 which stated that the distance between rows of sugarcane should be the smallest which permits cultivation with modern equipment. Row spacings from 60 to 90 cm can still be found where sugarcane is produced by man and animal power. Wider spacings

are popular where some mechanization has taken place.

Among the earliest documented experiments on row spacing were those of W. C. Stubbs[20,22], who found that decreasing interrow spacing increased yields of *S. officinarum*. Even though he obtained as much as 23% more cane from 91 cm than from those with 150 cm rows, Stubbs preferred the latter because of the economy of seed cane. Spacing experiments have been repeated with different varieties and in different parts of the world. Of the 17 row-spacing experiments in 12 cane-growing regions (Table 1), decreased interrow spacing increased yield from 5 to 89% in all but one test, with an overall average increase of 31%. Seven tests have spacings of 61 cm or less, and these included some of the larger increases as well as the only decrease. That none of the comparisons reviewed by Webster[22], and less than half of the experiments in Table 1 included treatments with row spacings of less than 61 cm is probably due to pragmatic reasons relating to planting and cultivation.

TABLE 1. Increased sugarcane yields through decreased row spacing.

Location		Harvests no.	Interrow spacing (cm) from	to	Average yield wider spacing t/ha	Average change closer spacing %	Age at harvest mo	Reference
Mississippi, USA	32°N	6	182	91	52	+35	8	(3)
	31°N	6	182	91	54	+70	8	(3)
Georgia, USA	31°N	3	168	107	60	+25	8	(8)
Louisiana, USA	29°N	4	182	61	85	+89	9	(12, 13, & unpubl. data)
		7	182	91	82	+31	9	(16)
Florida, USA	27°N	3	150	50	98	+41	12	(Gascho, unpubl. data)
		3	152	91	90	+ 5	12–16	(16)
Taiwan	23°N	2	120	60	70	+11	8–9	(9)
		2	120	80	50	+30	–	(5)
Hawaii, USA	20°N	1	240	150	222	+36	20	(6)
Puerto Rico, USA	18°N	3	152	91	142	+17	–	(Samuels unpubl. data)
		6	152	91	127	+16	–	(14)
Dominican Republic	18°N	3	175	106	90	+48	12–18	(15)
Philippines	15°N	1	125	50	148	+63	–	(17)
Rhodesia	22°S	2	200	50	134	+ 6	12	(1)
Australia	27°S	2	140	50	80	+48	12	(4)
South Africa	30°S	2	137	46	144	– 8	12–20	(21)
		2	218	89	109	+16	12	(2)

Sugarcane grown on closely spaced rows is believed to succeed in high latitudes because of the maximum utilization of both land area and incident light during a growing season shortened by frost. This view is supported by results from frost-prone areas (Georgia, Mississipi, Louisiana, Table 1). Results

from tropical areas with cane grown on a 12-month regime generally showed moderate increases, but limited results from crops of longer duration have shown negative effects. Colson[6] cited Maxwell's data which showed that cane grown in Hawaii for 18 to 20 months on 150 cm rows had yields 36% higher than from 240 cm rows. Cane grown on 120 cm rows yielded 20% less than that on 150 cm rows. Similar decreases with long-cycle cane on close rows were observed in South Africa (Table 1).

Aside from the South African results with long-cycle cane, the six remaining cases with row spacings of 61 cm or less (Table 1) showed an increase in yield 43% above that of the wider spacing with which each was compared. Even larger increases have been reported for individual comparisons, with an increase of 83% with variety H 51-8029 spaced at 50 cm in Australia (Bull[4]), and increase of 140% with CP 65-357 at 30 cm in Louisiana (Matherne[12]). The results could be dismissed as vagaries caused by random chance, inadequate buffer in small plots, or unusual seasonal variations. However, as these exceptionally high yields were produced on exceptionally close spacings, these results should be considered in terms of the relationship between interplant spacing and yield.

The two primary components of yield of cane are stalk population and weight. Stalk population per unit area is directly affected by inter and intrarow spacing, and changes rapidly with close spacing (Fig. 1). Given, for simplicity, equidistant spacing between plant, one stalk per plant, and increments of 25 cm, there is relatively little change in area per plant (−24%) and population per hectare (+31%) when the interplant distance is decreased from 2.0 m to 1.75 m. A large decrease in area per plant and increase in population per hectare occur at closer intervals. Reducing the interplant spacing from 1.00 to 0.75 m increases the theoretical population of 79% and a reduction from 0.50 to 0.25 m is accompanied by an increase of 400%. Curve of Fig. 1 indicates that as the interplant spacing decreases arithmetically, the population increases exponentially.

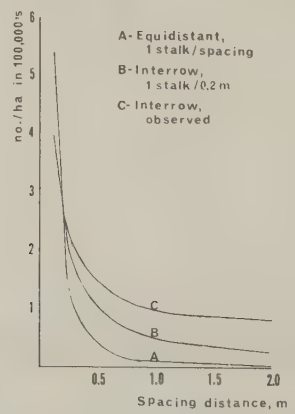

FIGURE 1. Theoretical and observed population of sugarcane with different interplant and interrow spacings.

A similar theoretical relationship exists with changes in row spacings. If again, for simplicity, it is assumed that there is one stalk per plant, and the interval between plants in a row is fixed (0.2 m), the population curve (curve B) for row spacings is similar to that for equidistant spacings (Fig. 1).

Spacing affects the number of stalks per plant (Irvine and Benda[10]), wide spacing produces plants with many tillers and crowded plants may have but one stalk. Since the decrease in stalk number per plant might affect the shape of the population curve, the available data on populations were averaged for different spacings (Anonymous[1], Boyce[2], Bull[4], Chen[5], Matherne[12] and

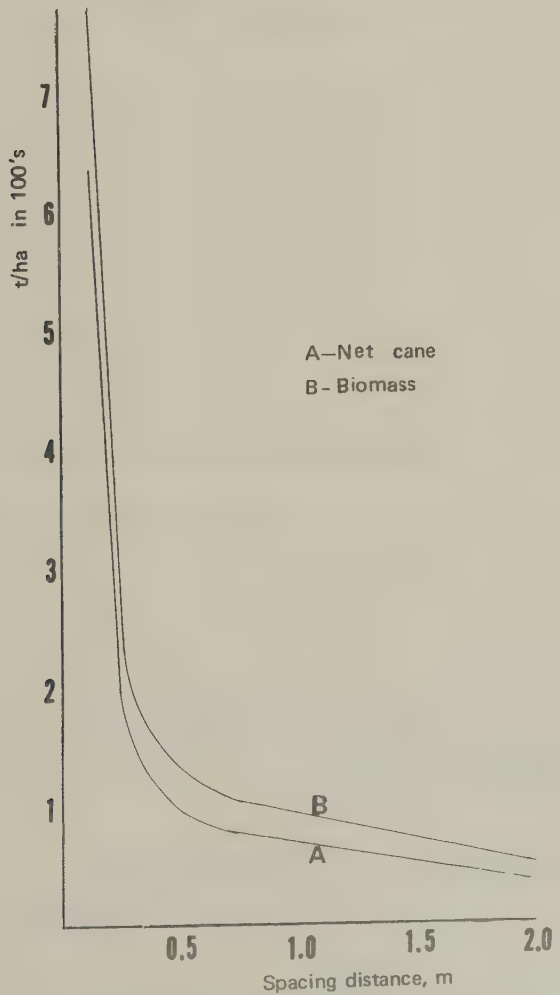

FIGURE 2. Calculated yield from interplant spacings based on theoretical population (Fig. 1) and observed decrease in plant weight with close spacing.

another unpublished data). The observed population curve (curve C) is higher than the theoretical curve at wide spacings where tillering increases stalk population, but approaches the theoretical curve (curve B) at close spacings (Fig. 1).

Spacing affects plant weight (Irvine and Benda[10] and Irvine *et al*[11]) through tillering and stalk weight. A 93% decrease in plant weight was observed over a 1.5 m reduction in interplant spacing. The decrease in plant weight with closer spacing is essentially linear. Using the values for plant weight and spacing, a yield curve was calculated (Fig. 2) which predicts much higher yields at spacings less than 0.6 m despite the decrease in weight per plant.

CONCLUSION

The results indicated that while wider spacing between rows or plants produces individual plants with higher yield, the greatest yield per unit of land area, for short cropping, will be obtained from the closest interplant spacings. The high yields at close spacing result from the exponential increase in stalk population.

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ESPACIAMIENTO DE CAÑA DE AZUCAR I. ASPECTOS HISTORICOS Y TEORICOS

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RESUMEN

Aparentemente el espaciamiento de las hileras evolucionó de espaciamientos estrechos a anchos para acomodar la mecanización. Una reseña de los experimentos llevados a cabo por más de 80 años demostró que los espaciamientos más pequeños producen aumentos en rendimientos de caña; reportándose respuestas más pronunciadas en áreas cañeras templadas y sub-tropicales, pero en los trópicos se han reportado aumentos significativos en rendimientos con espaciamientos más juntos. Para determinada área a medida que la distancia entre plantas disminuye aritméticamente, la población de plantas aumenta exponencialmente. Aunque con espaciamientos más juntos merma el peso de la planta y el número de tallos por planta, el efecto de la población es tal que el rendimiento teórico también aumenta exponencialmente con espaciamiento más junto.

SUGARCANE SPACING II. EFFECTS OF SPACING ON THE PLANT

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ABSTRACT

Intrarow spacing with 19 cm between plants on a 183-cm row produced significantly higher yields of biomass, net cane and sugar/ha when compared to intrarow spacings of 38 and 76 cm.

Equidistant spacings of 19, 38, 76, and 152 cm produced significant differences in fiber % cane, stalk diameter, and leaf area index, as well as yield of biomass, net cane and sugar/ha. There was no significant effect on the sugar content of cane.

Ten equidistant spacings ranging from 26.7 to 179.1 cm produced increases in plant population, biomass, net cane and sugar/ha with decreased spacing. Stalk diameter, shoot number, and plant weight decreased as interplant distance decreased. Varietal differences in yield of cane and sugar/ha were more pronounced with closer than with wider spacings. There was a significant correlation ($r = 0.71^*$) between varietal ranking in yield on closer and wider spacings, indicating that selections made on wide rows should perform adequately on closer rows.

INTRODUCTION

Sugarcane spacings trials have been conducted in many sugarcane producing areas. Although the results generally show increased yield of the crop with decreased interrow spacing, spacing studies have emphasized the crop rather than the plant. Irvine, *et al*[1] indicated no effect of spacing on sucrose content in the majority of spacing comparisons. Variable and contradictory results were reported for spacing effects on stalk height, number and weight, and on juice extraction and fiber.

Part of the variability could be due to the wide range of climate, soils, and varieties employed in the spacing trials. A further source of variability is inherent and results from the difficulty of controlling population and interplant distance when sugarcane is planted with seed pieces of several nodes. Furthermore, the tendency to exclude the very wide or very close spacings has limited the range of response, and interesting trends have been obscured by inadequate treatment range.

Some of these problems were examined in a series of three experiments in which interplant distance and population were controlled with some precision.

MATERIALS AND METHODS

Seed cane for the three experiments were selected from hot-water treated progeny and was judged free of sugarcane mosaic virus and ratoon stunting disease. Selected stalks were bundled and stored at 10°C for 4 to 6 weeks. Single-bud seed pieces (12.5 cm) were prepared by hand and were planted in vermiculite in peat pots (7.5 cm dia.). Potted cuttings were placed in a greenhouse (20°C min) and were watered as required and fertilized weekly with a dilute solution of ammonium nitrate. Leaves were clipped periodically. After transplanting to the field, all plants were fertilized with granular ammonium nitrate at a rate of 135 kg/ha in Experiment 1, and 340 kg/ha in Experiments 2 and 3. Weeds were controlled by hoeing (Expt. 1) or by hoeing and an aqueous spray of 2,4,5, trichlorophenoxy acetic and the sodium salt of asulam (Expts. 2 and 3). The sugarcane borer, *Diatraea saccharalis,* was controlled by bi-weekly applications of monocrotophos.

Experiment 1 was a comparison of three intrarow spacings on one inter-row spacing (183 cm). Treatments were established in a randomized block design with five replications. Potted cuttings of CP 65-357 were transplanted by hand from the greenhouse to the field on March 16 and 17, 1978; the cuttings were planted on raised rows typical of plantings in Louisiana. Plants were spaced in a line along the row with intrarow distances of 19, 38, and 76 cm; plots measured 4.6 x 5.4 m. Plants were irrigated immediately after transplanting. Plots were harvested after 8 months (Nov. 15 and 16, 1978), and measurements were made of total aboveground fresh weight (biomass cane), net weight of millable stalks, and brix and sucrose of juice. Biomass cane includes mature and immature stalks, tops and green and dead leaves.

Experiments 2 and 3 were comparisons of equidistant spacings in checker-board (Expt. 2) and wheel (Expt. 3) designs. Preparations for both experiments were similar. The field was flattened, chisel plowed, and harrowed, and terbacil (3-ter-butyl-5-chloro-6-methyluracil), a pre-emergence herbicide was broadcast in the field. Cuttings were transplanted so that the base of the shoot was 10 cm below the soil surface in holes 10 cm wide and 30 cm deep prepared with an auger. Excavated soil was returned to partially fill the hole. Transplants were irrigated immediately. Both experiments were started between April 10 and 18, 1978.

Experiment 2 was planted in a checkerboard design with four equidistant spacings; plants were spaced 19, 28, 76, and 152 cm within and between rows. There were two replications, one planted April 10, the other April 18, 1978. The test area of each plot was 9.3 m^2, and each test area was surrounded by a buffer row of plants with the same spacing. Thus, a 19-cm spacing plot was 11.8 m^2 and contained 324 plants, a 38-cm spacing plot was 14.5 m^2 and contained 100 plants, a 76-cm spacing plot was 20.9 m^2 and contained 36 plants, and a 152-cm spacing plot was 37.1 m^2 and contained 16 plants.

Periodic measurements were made of canopy height, height to the top visible dewlap (TVD), and total shoot population. Plots were harvested Oct. 23 and 24, 1978, 7 months after planting, and the total number of shoots and millable canes were recorded. Stalk length from soil level to TVD was measured, and leaf area was measured with a photometric leaf-area meter. Maximum diameter was determined by calipers. Fresh and dry weights were determined for the aboveground portion; millable stalks were then selected and cleaned of leafy material to determine the weight of net cane. Ten-stalk samples of biomass and net cane were taken from each plot for juice analysis (Meade and Chen[4]). Samples of cleaned cane weighing 36.3 kg were used for mill tests (Legendre and Henderson[2]) to determine juice extraction and fiber content.

Experiment 3 was planted in a wheel design (Nelder[6]) with three wheels as replications. The plants were transplanted as in Expt. 2, but spaced along the spokes of the wheel with each spacing (from center to periphery) 17 cm longer than the previous one. Each wheel had 30 spokes and 10 spacings (concentric circles) calculated to give about the same distance between plants on radius and arc. Each plant was approximately equidistant from its four neighbors. Ten varieties were used and three adjacent spokes of a wheel were planted to each variety. Nine varieties had attained commercial status in Louisiana, and the tenth was a Florida variety. The varieties were selected to represent differences in clonal age, ancestry, and canopy; five varieties had upright leaves and five had spreading leaves. The inner and outer concentric circles were buffered with plants of CP 65-357 spaced in accordance with the experimental design.

As with Expt. 2, measurements of TVD and canopy height and counts of population were made periodically. Harvest began on Dec. 5, 1978, eight months after planting. Using the center spoke of each variety, for each spacing, the biomass and net cane weight were determined. The longest stalk in each stool was selected and its length from soil level to TVD was measured and its diameter at midpoint was determined. Observations were made on flowering, and all leaves from the varieties Co 281 (erect leaves) and F 36-819 (spreading leaves) were retained for leaf area determination. The total net cane from each spacing was milled and the juice was analyzed for brix and sucrose. Sugar per ton and per hectare were calculated using varietal correction factors determined by this laboratory.

RESULTS

The closest of the three intrarow spacings (Expt. 1) on the standard 183-cm row showed a significant ($p = 0.05$) increase in yield of biomass, millable cane, and sugar per hectare compared to the other two, which were not different from each other (Table 1). There was no significant effect of spacing on the sugar content of the cane. Both biomass and net cane increased slightly more than 20% when the spaces between the plants in the rows were reduced from 76 to 19 cm.

TABLE 1. Sugarcane yield components as affected by varied intrarow spacing on 183 cm rows.

Spacing	Yield component			
treatment	Biomass	Net cane	Sugar	
cm.	t/ha	t/ha	t/ha	% cane
19	142 a	91 a	12 a	12.8 a[1]
38	128 b	79b	10 b	12.4 a
76	117 c	74 b	9 b	12.2 a

[1]*The means of a column followed by the same letter are not significantly different at the 0.05 level of probability.*

TABLE 2. Effects of equidistant spacing on yields and components.[1]

Category	Spacing Treatment, cm				LSD
	19	38	76	152	0.05
Shoots, in 1000's	228.00	109.00	83.00	58.00	76.90
Biomass, fresh, t/ha	217.00	179.00	149.00	80.00	106.40
" dry t/ha	61.00	46.00	37.00	20.00	22.60
Cane, net, t/ha	171.00	138.00	112.00	60.00	85.40
Sucrose, t/ha	16.50	12.00	9.00	4.70	6.08
" % cane	9.63	8.72	7.95	8.07	NS
" % crusher j.	14.06	12.74	11.68	11.97	NS
" % normal j.	13.85	12.53	11.75	11.67	NS
Brix, % normal juice	17.93	16.25	15.06	15.65	NS
Bagasse, % cane	25.78	25.46	23.35	24.30	NS
Fiber, % cane	11.49	11.15	10.47	10.08	1.19
Theoretical sucrose recovery % cane	10.25	9.41	8.55	8.66	NS
Theoretical t/ha	17.50	13.00	9.60	5.20	4.24
Stalk height, TVD, cm	250.00	274.00	282.00	187.00	NS
Stalk djameter, cm	2.08	2.39	2.51	2.77	0.432
Stalk weight, kg	0.82	1.65	1.79	1.41	NS
Nodes/stalk, no.	14.00	18.00	19.00	15.00	NS
Greenleaves/stalk, no.	8.00	10.00	11.00	10.00	NS
Leaf area/stalk, m^2	0.36	0.60	0.57	0.58	NS
Leaf area index	8.20	6.50	4.80	3.30	3.34

[1]*Single node cuttings transplanted to the field in April and harvested October 23, 24, 1978. Variety CP 65-357, 2 replications.*

The results of Expt. 2 are summarized in Table 2. The experiments where intrarow and interrow distances were also equal showed yield increases with decreased spacing (Expts. 2 and 3). There were significant differences in plant populations at the time of planting as well as at subsequent dates (data not shown), and at the date of harvest (Table 2). There was a significant difference in leaf area index when the 19-cm spacing was compared to the 152-cm spacing. There was also a significant difference in fresh and dry weight of biomass/ha

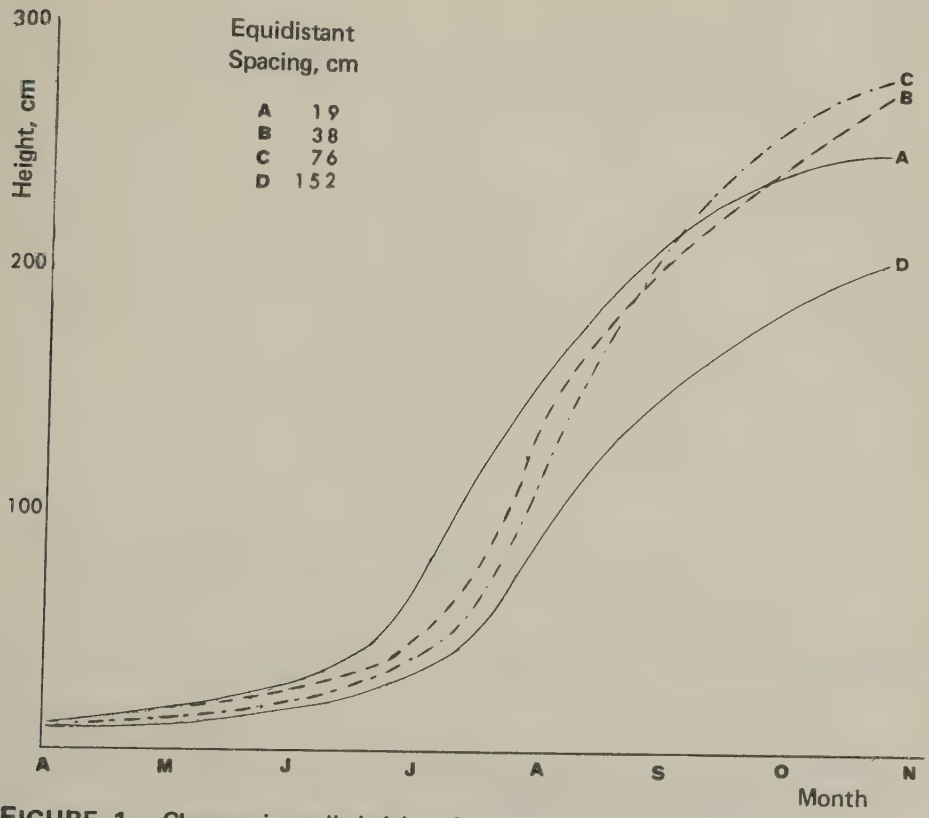

FIGURE 1. Changes in stalk height of sugarcane variety CP 65-357 as affected by spacing.

and in sugar/ha. The yield of millable stalks increased significantly with decreased spacing; the yield from the 19-cm spacing was almost three times that from the 152-cm spacing.

The values of sugar per ton were not significantly different among spacings, but the values of sugar per hectare were significantly different; the sugar yield of the 19-cm spacing was more than three times that from the 152-cm spacing. Although differences in bagasse content with spacing were not significant, fiber increased in cane with decreased spacing. The 11.49% fiber at the 19-cm spacing was significantly higher than the 10.08% for the 152-cm treatment The differences in diameter with decreased spacing were also significant, and stalks became progressively thinner with crowding.

Among spacing treatments, the stalks of harvest did not differ significantly in height, number of nodes, number of green leaves, and leaf area. Before harvest, TVD height and canopy height (Fig. 1) showed persistent differences and the early rapid growth of plants in the 19-cm spacing was maintained until the last phase of the growing season when plants at 38- and 76-cm spacings surpassed it in height.

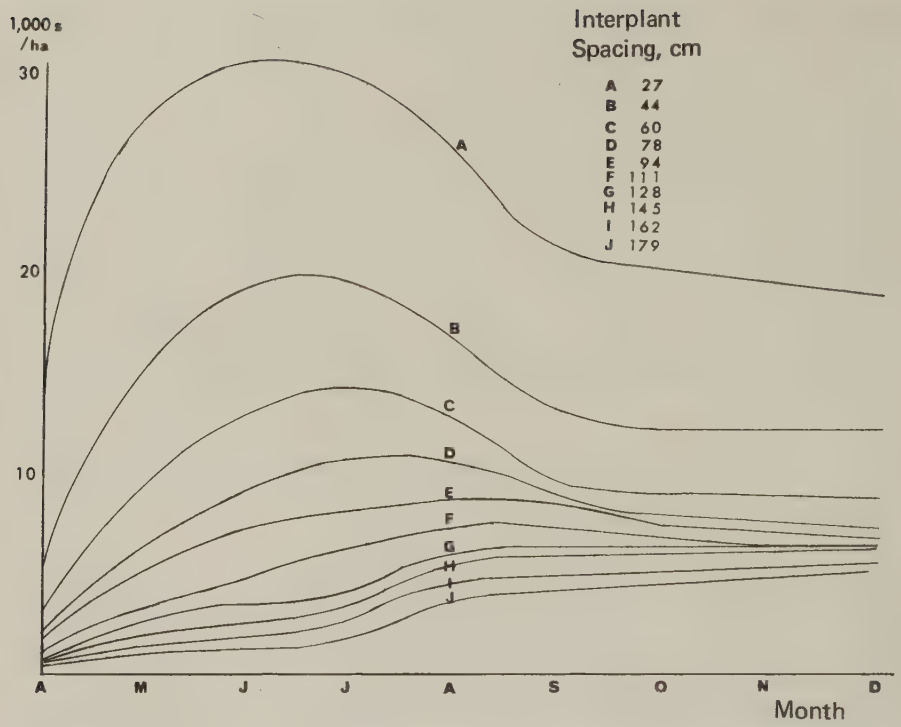

FIGURE 2. Changes in shoot population as affected by spacing, average of 10 varieties.

The number of stalks at different spacings in the wheel design (Expt. 3) is shown in Fig. 2. As in Expt. 2, there are wide differences in shoot number (population) from planting to harvest in the 10 different spacings treatment. The closest spacing showed an early rapid rise in population during the first 3 months and then a drop, first abrupt, then more gradual, for the remainder of the season. Only the three closest spacings (27 to 60 cm) maintained high populations until harvest.

The leaf area index (LAI) of the two varieties sampled showed almost a tenfold increase from the widest to the closest spacing. The increase in LAI is influenced by population density, and it occurred even though the leaf area per plant showed a steady decrease with spacing (Fig. 3). Much of the increase in LAI occurred at the two closer spacings (27 and 44 cm).

Similar increases at the closer spacings can be seen in Fig. 4 for biomass, millable cane and sugar per hectare. Biomass increased steadily from the widest to the closest spacing with an abrupt upward turn at the closest spacings. Since the stalks from the major portion of the plant's weight, a close association between biomass and net cane is expected.

The wide variation in juice sucrose within a variety (perhaps due to

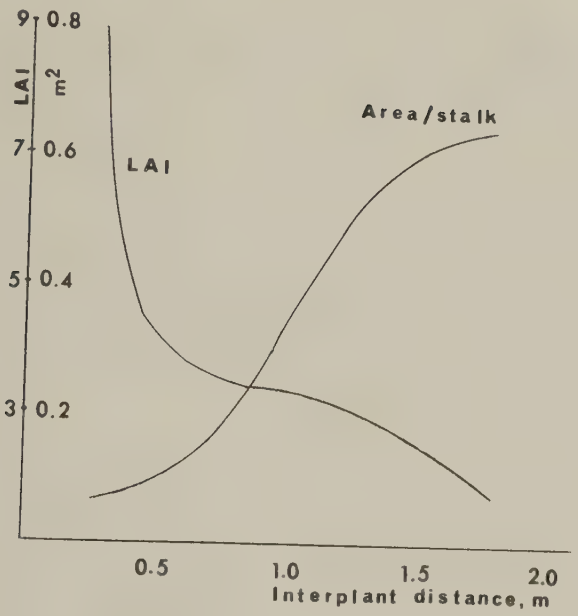

FIGURE 3. Leaf area per stalk and leaf area index as affected by equidistant spacing.

lodging) was apparently not related to spacing. There was not sufficient cane available from the individual plots for milling tests, but diameter measurements indicated a decrease in diameter with crowding (Fig. 5) suggesting increased fiber content.

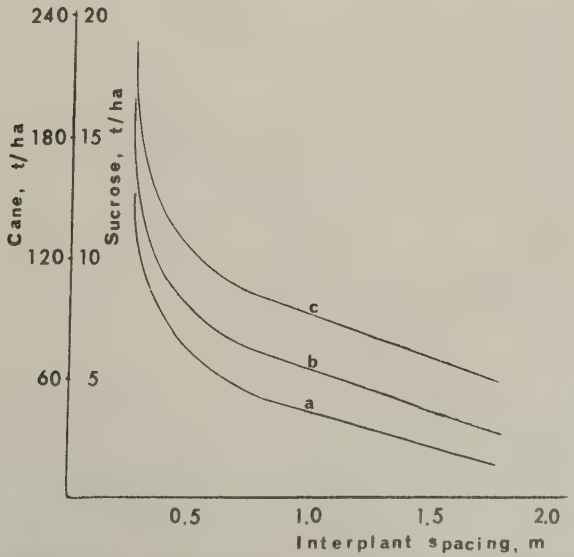

FIGURE 4. Effects of equidistant spacing on yields of net cane (a), biomass (b), and sucrose (c), per hectare.

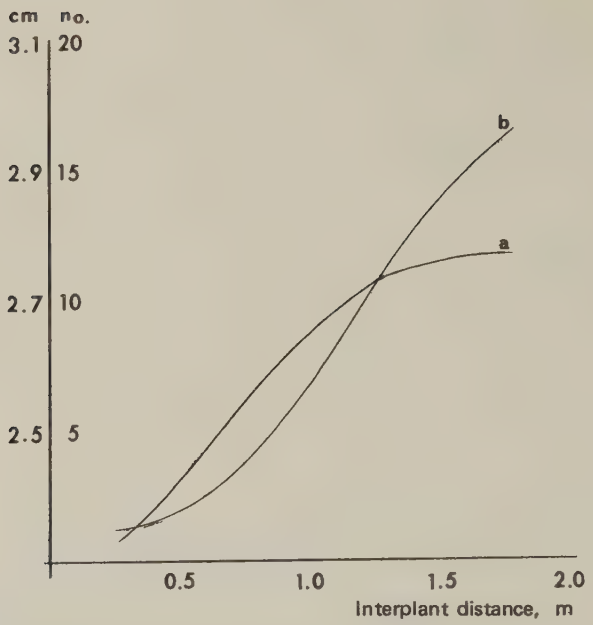

FIGURE 5. Effects of equidistant spacing on millable stalk diameter (a) and shoot number per plant (b), average of 10 varieties.

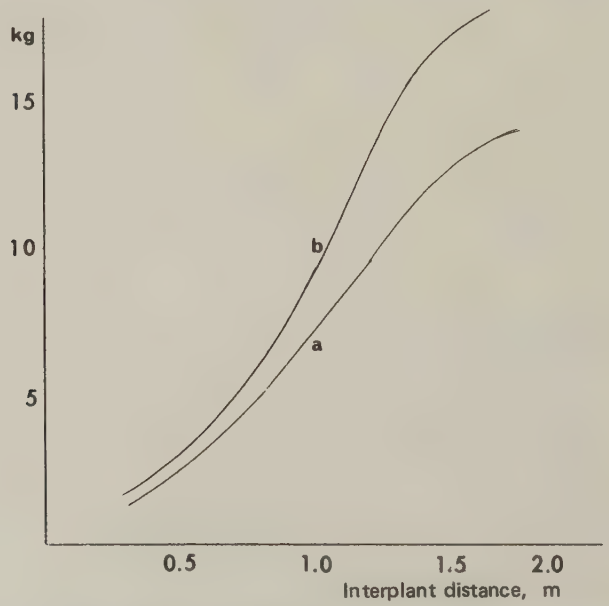

FIGURE 6. The effects of equidistant spacing on plant weight expressed as net cane (a) and biomass (b).

Both biomass and net cane weight per plant decreases as the interplant spacing decreased (Fig. 6), as did the number of tillers per plant. As in Expt. 2, the tallest stalks were from the closest spacings early in the growing season, and later, from plants in the intermediate spacings. The stalks from the widest spacings remained shortest for tne entire season.

The average sugar yields of each variety at the three closest and three widest of the 10 spacings were ranked (Table 3), and CP 65-357 and Co 290 were the leading and lagging varieties, respectively. A comparison of variety ranking in yield at the closer and wider spacings gave a significant correlation ($r = 0.71^*$). Varietal effects appeared more pronounced for the closer than for wider spacings, since the highest-yielding variety produced 2.4 times more than the lowest-yielding variety on closer spacings and 1.6 times more on wider spacings.

TABLE 3. Yields of sugar/ha of 10 varieties expressed as an average of the three widest and three closest spacings.

	Tons of sugar per hectare			
Variety	Average of 3 closer spacings	Rank	Average of 3 wider spacings	Rank
CP 65-357	20.09	1	7.22	1
F 36-819	17.71	2	5.63	6
CP 44-101	16.08	3	5.34	8
L 62-96	15.58	4	6.12	3
L 60-25	14.84	5	6.32	2
Co 281	11.39	6	5.18	9
N Co 310	10.38	7	5.72	4
CP 36-13	10.02	8	5.49	7
CP 61-37	9.91	9	5.72	5
Co 290	8.36	10	4.62	10
Average	13.44		5.74	

DISCUSSION

The closely spaced sugarcane plant grows rapidly without pause for tillering, and may grow slowly when conditions become limiting. The plant at harvest has only one or two thin stalks, and has characteristically fewer leaves per plant, less leaf area, less total plant weight, and higher stalk fiber than do plants on wide spacing. The widely spaced plants grow slowly in height while producing abundant tillers over a long period. The eventual production of many thick stalks by widely spaced plants gives a false impression of high yield.

Large increases in yields of cane were obtained with close spacing. Results from the 19-cm spacing in Expt. 2 (217 t biomass and 171 t net cane/ha) and the 27-cm spacing in Expt. 3 (228 t biomass and 186 t net cane/ha) predicted high yields for very close spacings.

These yields were achieved despite a short growing season (7 and 8 mos., respectively), and despite a reduction in diameter, number of stalks per plant, and plant weight. The high yield in closely spaced, short-season sugarcane is correlated with population density (Matherne and Irvine[3]) and population density increases exponentially with decreased spacing (Irvine *et al*[1]).

The data in this study indicate no decrease in sugars with decreased spacing.

In contrast to rice (Matsushima *et al*[5]) and maize (Pendleton *et al*[7]), crops in which erect leaves are associated with high yield, erect leaves had no effect on sugarcane yields. Five of the 10 varieties in Expt. 3 have been selected for erect leaves; these were Co 281, CP 36-13, CP 44-101, L 60-25, and L 62-96. The remaining five varieties were selected for spreading leaves. The two groups differed by only 0.04 t/ha of sugar on the wider three spacings and 0.13 t/ha on the closer three spacings (Table 3).

The importance of varietal selection in spacing trials is indicated by the much greater difference in yield among varieties on closer spacings (11.7 t/ha) than on wider spacings (2.6 t/ha). The overriding effect of spacing on yield is indicated by the yield of the poorest variety from the closer spacings which was greater than that of the best variety from the wider spacings.

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ESPACIAMIENTO DE CAÑA DE AZUCAR II. EFECTOS DE ESPACIAMIENTO SOBRE LA PLANTA

J. E. Irvine y G. T. A. Benda

RESUMEN

Con el espaciamiento de 19 cm entre plantas dentro de la hilera en hileras de 183 cm de ancho se produjeron significativamente mayores rendimientos de biomasa, caña neta y azúcar/ha en comparacion con espaciamientos de 38 y 78 cm dentro de la hilera.

Espaciamientos equidistantes de 19, 38, 76 y 138 cm produjeron diferencias significativas en fibra % caña, diámetro de tallo, indice de´ area foliar, como también rendimiento de biomasa, caña neta y azúcar/ha. No hubo afecto significativo sobre el contenido de azúcar en la caña.

Diez espaciamientos equidistantes variando desde 26.7 hasta 179.1 produjeron aumentos en la población de plantas, biomasa, caña neta y azúcar/ha con una disminución del espaciamiento. Diámetro de tallo, numero de tallos, y peso por plantas disminuyeron a mediado que disminuyó la distancia entre las plantas. Diferencias varietales en cuanto a rendimiento de caña y azucar/ha eran más pronunciadas con espaciamientos mas juntos que con espaciamientos más anchos. Hubo una correlación significativa (r = 0.71*) entre rango varietal en rendimiento en espaciamientos más estrechos y más anchos, lo que indica que las selecciones que se hacen en hileras anchas se comportan adecuadamente en hileras más estrechas.

SUGARCANE SPACING III. DEVELOPMENT OF PRODUCTION TECHNIQUES FOR NARROW ROWS

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ABSTRACT

A replicated small plot test showed that cane and sugar yields/ha from 61-cm rows exceeded those from 183-cm rows by more than 60%. There were no significant differences in yield whether N was applied as a solid, or as a split liquid application through trickel irrigation.

A replicated large-plot test showed that cane and sugar yield/ha from 61-cm rows exceeded those from 183-cm rows by more than 80%. Triple-drill rows were not significantly different from 61-cm rows in terms of yields of cane or sugar/ha. Sub-surface drainage had no effect on plant cane yields even though water table levels in drained and undrained plots were significantly different.

Large trials gave varied yield results from 61-cm and triple-drill plantings, partly as a result of inadequate soil cover at planting. Wholestalk and cut-chop harvesters cut closely spaced plantings adequately when fields were dry and cane was erect. Lodging was pronounced in the heavy yielding, closely spaced treatments, and the development of an economical harvesting and transport system is foreseen as a major problem.

INTRODUCTION

Historically, higher yields have been obtained with closer spacing (Irvine *et al*[3]) and rows spaced as close as 91 cm have given significant increases in yield (Matherne[4]). Accordingly, a preliminary, unreplicated test was initiated in 1974. Treatments included rows spaced 30, 61, 91, and 183 cm apart, plus one involving 213-cm rows with two lines of cane 61 cm apart (double drill). Whole cane stalks were planted end-to-end and covered with hoes. Contrary to local practice, the rows were left flat and uncultivated. Weeds were controlled chemically and the plants were heavily fertilized (220 kg N/ha). Harvests of the plant cane and two ratoon crops produced average yields from the single and double-drill rows that were slightly higher than usual (85 and 96 t/ha, respectively), and yields from 91-cm rows (112 t/ha) approximated previous results (Matherne and Irvine[5]); the 61-cm and 30-cm

spacings averaged 170 and 169 t/ha, respectively, twice the average yield from the standard row spacing.

To confirm these results and to develop production methods for closely spaced rows, a series of experiments has begun, the results of which are reported here.

MATERIALS AND METHODS

The series of experiments included a replicated small plot test, a replicated large plot test, and an unreplicated, multiple location planting. The same variety, CP 65-357, was used in all experiments.

The replicated small plot test was begun in the fall of 1976, in a field of Mhoon silty clay loam. The field was leveled and crowned before planting to enhance surface drainage. Furrows were opened with a small tractor fitted with small plows to produce spacings of 61, 91 and 183 cm, plus two furrows 46 cm apart (double drill) centered on a 183-cm row. Close row spacings (61 and 91 cm) and double-drill plantings were planted with one stalk laid end-to-end, and the single-drill 183-cm spacing was planted with two running stalks. Individual plots were 6 m long and 9 rows wide. There were five replications split-plot design with interrow spacings as sub-plots. The whole plot treatments were ammonium nitrate (at 330 kg N/ha) application, applied as a solid, or dissolved in water and applied in three increments through a trickle-irrigation system. Plots were not cultivated and weeds were controlled with Terbacil and spot applications of Silvex.

Shoot populations and leaf area were determined throughout the growing season. The hand-harvested cane was cut only at the base and the entire plot was weighed for biomass yield. Yield of net cane was determined by removing tops and leafy trash from 40-kg biomass samples; the proportion of net cane to biomass cane was used as a factor to determine whole plot yields of net cane. Only plant cane was studied; the experiment was destroyed following excessive damage by hauling wagons after harvest.

A problem with closely spaced rows is having soil available to cover the cane in the furrow after planting. Personnel at the National Tillage Laboratory (USDA, Auburn, AL) suggested the use of tiller-bed shapers developed by FMC Corp., Minden, L.A. (Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products or vendors that may also be suitable.) The machines pulverize the soil with rotating knives, and the shapers from the planting furrows and compress the sides of the furrow to prevent sliding of the soil. Furrows 15 to 20 cm deep can be prepared mechanically and interrow spacing is varied by repositioning the knives and shapers.

The replicated large-plot test involved a split-plot design with four replications. The whole plot treatments were sub-surface drainage and no-drainage

and the subplots included three spacing treatments: 61-cm and 183-cm single drill, and 183-cm triple (46 cm between drills). A 3.2 ha precision-graded field of Commerce silt loam was divided into eight main plots (0.4 ha). All plots were provided with subsurface drains (10-cm dia) placed 1.2 m below and 18 m apart. Collector lines carried free water to sumps. The sumps for the undrained plots remained unpumped. To prevent drains in one plot from affecting another plot, each plot was wrapped with a continuous polyethylene barrier extending from 60 cm below the surface to a depth of 240 cm. Details of this installation will be published elsewhere.

Three large unreplicated trials of closely spaced rows were initiated in the fall of 1977. The first was planted in Lafourche Parish on Mhoon silty clay loam, the second in St. Mary Parish on Iberia silty clay loam, and the third in Terrebonne Parish on Commerce silt loam. In all three locations, fields were leveled, disc-harrowed, and planed before furrows were opened. In the Terrebonne Parish planting, the field was thoroughly chisel-plowed before it was disced. The tiller-shaper furrowed nine 61-cm rows or three triple-drill rows at a time. Planting was done using plantation cane and equipment. Front-mounted discs on a tractor moving slowly covered the 61-cm rows, and rear-mounted discs on a tractor moving rapidly covered the triple-drill rows. At the Lafourche and St. Mary plantings, fields with 61-cm and triple-drill treatments were planted at the same time as adjacent fields that were planted by standard plantation practice (183 cm, single-drill rows). Fields of the three plantings approximated 1 ha each at both locations. The Terrebonne planting consisted of 61-cm rows only with sub-surface drainage on 3 ha.

Neither the replicated large-plot test nor the three large trials was cultivated. Weeds were controlled with recommended chemicals, and insects were controlled with aerial applications of azin-phosmethyl. Fertilizer was applied as ammonium nitrate at 330 kg N/ha. The yield of the standing crop was estimated from areas (31 m^2) in which the cane was hand-cut, topped and weighed. Samples of 15 stalks were taken from each area, milled, and analyzed for sucrose content (Mead and Chen[6]). Four areas were harvested in each spacing treatments for every trial planting, and one sample area was harvested in each sub-plot of the large-plot experiment. After completing the harvest of the large-plot with whole-stalk harvesters, ground loss in each sub-plot was estimated from other 31 m^2 areas in which the millable cane left in the field was gathered and weighed.

Observations were made on the ability of several types of commercial harvesters to operate on close-row spacings. The harvesters used included three whole-stalk harvesters (Cameco, J and L, and Thomson) and three cut-chop harvesters (Cameco, Class, and J and L). Two of the whole-stalk harvesters were modified production models with double-bottom cutting blades.

RESULTS AND DISCUSSION

In the replicated small-plot test, the 61-cm interrow spacing treatment yielded 142 t/ha of net cane (Table 1), three times the state average yield.

TABLE 1. Yield components of sugarcane grown on several row spacings[1]

Interrow spacing	Millable stalk number	Leaf area index	Yield of biomass		Yield of net cane	Crusher juice sucrose	Sugar yield
			Fresh	Dry			
	in 1000's		t/ha	t/ha	t/ha	%	t/ha
61 cm	123	4.14	187	60	142	18.72	19.88
91 cm	106	3.71	146	50	111	18.86	14.80
DD							
183/46 cm	88	3.17	128	41	97	18.49	13.16
183 cm	90	3.33	115	38	87	18.57	12.10
LSD (0.05)	16.6	ns	20.4	6.7	15.5	ns	2.33

[1] *Data from plant cane crop, 5 replications, split-plot design with non-significant main effect (N application).*

TABLE 2. Yield components of plant cane with drainage and spacing varied in a split-plot design

Treatment	Yield components					
	Stalk number	Stalk weight	Yield standing crop	Crusher juice sucrose	Sugar yield	Ground loss
	1000's/ha	kg	t/ha	%	t/ha	t/ha
Spacings[1]						
61 cm, single drill	115	1.04	111	18.23	15.17	52
183 cm, triple drill	90	1.05	102	18.03	13.81	31
183 cm, single drill	55	1.23	59	17.97	7.95	11
LSD, spacings (0.05)	42.8	0.103	22.7	NS	1.67	21
Drained	86	1.11	92	18.28	12.74	34
Undrained	94	1.11	89	17.87	11.88	28
LSD, drainage (0.05)	NS	NS	NS	NS	NS	NS

[1] *61-cm rows were flat, 183-cm rows, both single and triple-drill, were slightly raised.*

Yields from the 91-cm rows were 111 t/ha. These yields and those from single and double-drill rows (183 cm) were similar to previous results (Matherne and Irvine[5]). Yields of biomass, a useful parameter when sugarcane is considered as an energy crop, were high, the high yields per hectare were associated with increased populations (Table 1). The weight of individual stalks was less on 61-cm rows (data not shown), and spacing had no effect on sucrose content. In this test, the nitrogen application method had no influence on yield.

Populations in the replicated large-plot test were significantly different among spacing treatments. The highest population was in the 61-cm rows. Stalks were significantly heavier on wide rows (Table 2). The yield of cane, however, was significantly lower on wide rows than on either 61-cm or triple drill rows. As numerical differences in sucrose content were not significant, the significant increase in sugar per hectare for close spacing is largely due to the increase in cane yield. All plots were harvested with whole-stalk harvesters fitted with dual base cutters. The quantity of millable cane left behind (ground loss) was significantly different among spacing treatments. The lowest ground loss occurred with the widest spacing where there was less cane to harvest and where the cane was erect; these are the conditions under which the whole-stalk harvesters were designed to operate.

In the analysis of variance of the replicated large-plot test, significant differences were found only in the sub-plots (spacings) and none of the parameters showed differences in main effects (sub-surface drainage). The drainage treatments were effective on controlling water tables. Significant differences in water table levels (piezometric) occurred twice during the 1978 growing season, and again during the winter following plant cane harvest, when recorders showed continually elevated water tables in undrained plots until the end of March, 1979. Water table control was not expected to affect plant cane yields since the effect of high water tables has been on ratoon crops in years following heavy winter rains (Carter[1]).

The yield from the large trial (3.4 ha) in Terrebonne Parish with 61-cm rows was 117 t/ha (Table 3), similar to the yields in the replicated large plot test in the same area (Table 2). Yields from the Lafourche and St. Mary Parish plantings were less, the 61-cm rows having 83 and 74 t/ha, respectively, and the triple-drill rows having 85 and 79 t/ha, respectively (Table 3). The average for closely spaced plantings for both locations was 17% higher than yields from adjacent single-drill plantation fields. This increase compared poorly with the 80% increase obtained in the replicated large plot test. The low yields in these two trial plantings can be attributed primarily to poor stands caused by insufficient soil cover, as well as inadequate pre-plant, soil preparation, and, at one location, inadequate pest control.

Six harvesters were used for various periods in harvesting the closely spaced plantings in 1978. None of the machines was designed for the conditions imposed, but most could harvest adequately when the cane was erect and fields were dry. The longer a machine was used and adjusted, the better the performance. Cutting 110 t/ha cane with 1 t/ha ground loss and 6% trash

TABLE 3. Yield components of plant cane grown on narrow rows in large application trials at three locations

Treatment	Location								
	Lafourche Parish			St. Mary Parish			Terrebonne Parish		
	Yield of standing crop	Crusher juice sucrose	Yield of sugar	Yield of standing crop	Crusher juice sucrose	Yield of sugar	Yield of standing crop	Crusher juice sucrose	Yield of sugar
	t/ha	%	t/ha	t/ha	%	t/ha	t/ha	%	t/ha
61 cm, single drill	83	18.35	11.31	74	19.83	10.87	117	17.76	15.29
183 cm, triple drill	85	18.60	11.72	79	19.55	11.48	–	–	–
183 cm, single drill	72	18.15	9.67	65	19.67	9.45	–	–	–

in cane was the best performance record. The cut-chop harvesters performed better on 61-cm rows than did whole-stalk harvesters. Triple drill rows were easier to harvest for all machines than 61-cm rows, erect or lodged. Triple drills were easier to follow and the slight water furrow allowed gathering attachments to penetrate under fallen stalks.

Furrow preparation with the tiller-shaper used in these tests was encouraging, but the large-scale plantings made in 1977 were inadequately covered and stands were affected. An improved tiller-shaped gave deeper furrows and adequate covering was possible. Five new plantings were made in 1978 using this machine and stands were improved. Stands that mature a large population of millable stalks are highly correlated with yields of cane (Matherne and Irvine[5]). Stand reduction can be more important in close than in wide spacings, for the loss of half of the population at 30-cm spacings is a much larger loss than at 150-cm spacings. Faulty covering is likely to cause the loss of a long portion of a row, and compensation through tillering is less likely in close than in wide rows (Irvine and Benda[2]).

Triple-drill plantings, or comparable wide-furrow plantings, would seem to offer immediate help to increase tonnage. Harvesting with modified whole-stalk harvesters would permit the continued effective topping necessary with Louisiana's frequently frozen cane. Plantings of 61-cm rows, or the even closer spacings that might be achieved by broadcast planting, have a higher yield potential than those of triple-drill rows. However, the development of a practical system to plan and harvest fields of this type is a long-term goal.

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ESPACIAMIENTO DE CAÑA DE AZUCAR III. DESARROLLO DE TECNICAS DE PRODUCCION PARA HILERAS ESTRECHAS

J. E. Irvine, L. A. Richard, D. D. Garrison, W. R. Jackson, R. J. Matherne, C. Camp y C. Carter

RESUMEN

Un experimento replicado de parcelas pequeñas demostró que los rendimientos de caña y azúcar/ha en hileras de 61 cm excedieron los de hileras de 183 cm por más de 60%. No hubo diferencia significativa en rendimientos sea que el N fuera aplicado en forma sólida, ó en forma líquida con aplicación separada a través de riego por goteo.

Un experimento replicado de parcelas grandes demostró que los rendimientos de caña y azúcar/ha de hileras de 61 cm excedieron los de hileras de 183 cm por más de 80%. Hileras sembradas en triple no eran significativamente diferentes a hileras de 61 cm en cuanto a rendimientos de caña y azucar/ha. El drenaje subterráneo no afectó los rendimientos de caña de la plantilla aunque los niveles de agua freática en parcelas drenadas y no drenadas eran significativamente diferentes.

Pruebas de grande escala dieron resultados variables en rendimiento en siembras en hileras de 61 cm y en triple, parcialmente como resultado de no cubrir adecuadamente al sembrar. Los cosechadores de caña entera y repicada cortaron adecuadamente las siembras espaciada estrechamente cuando los campos estaban secos y la caña erecta.

Fué marcado el encamado de la caña en los tratamientos de alto rendimiento estrechamente espaciados, y el desarrollo de un sistema económico de cosechar y transportar se anticipa como un problema mayor.

FARM PRODUCTION DATA ANALYSIS WITH RESPECT TO CONTROLLABLE FACTORS, AGRONOMIC INPUTS AND ENVIRONMENTAL CONDITIONS FOR SYNCHRONIZATION OF SUGARCANE FIELD AND FACTORY OPERATIONS

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ABSTRACT

The importance of quantitative application of various inputs to sugarcane production is well established. These inputs include the variety, crop, fertility level, disease and insect control, plant spacing and population density factors, application of water to meet atmospheric demands and removal of excess water from the root zone. The importance of optimal sequencing of inputs and timing of applications with respect to environmental factors has received some attention. The importance of the timing and sequencing of crops to attain an optimal district production to a given sugar mill has also gained recognition.

This research describes the procedure used for the selection of significant factors and the subsequent modelling of those factors for the prediction of sugarcane rendement and tonnage yield with age of the crop and by month of the year. The primary factors determined were the rainfall plus irrigation inputs in the 1 to 30 day period and 31 to 60 day period before harvest. Other factors were the year in which the crop was grown with respect to an integrated set of climatic factors, the age of cane at harvest, the month of harvest, the variety and the crop type.

The results of various trials were compared and one particular model was analyzed graphically to show the effects of varying levels of inputs or factors on the rendement and the tonnage yields predicted by the models. The role of these models in synchronization of farm and factory operations is discussed.

INTRODUCTION

A production function is the technological summary of the relationship between inputs, expressed as the independent variables, and the resulting maximum attainable output, as the dependent variable. The general statement for the pro-

duction function with n inputs is:

$$Y = f(X_1, X_2 \ldots . X_n)$$

It is more specifically stated with only two variable inputs, X_1 and X_2, and with all other inputs, X_3 through X_n, assumed constant as:

$$Y = f(X_1, X_2 / X_3, \ldots . X_n)$$

In general a curvilinear relationship is expected. The application of the law of diminishing returns is generally interpreted to mean eventually dimishing marginal productivity (Baumol[3]) and has led to the interpretation of crop yields with water inputs to follow a generalized polynomial relationship (Early[9]). The methodologies for analysis and interpretations of production functions for economic optima were extensively presented by Heady and Dillon[15].

Humbert[17] reported the loss in yield due to excessive applications of moisture in the cane ripening period in Hawaii. In that environment, forced ripening was best achieved through moisture control, while the other management option was nitrogen depletion. Barnes[2] reported the effects of the weather factors on the optimal harvest time of sugarcane, and advocated that irrigation be withheld six weeks prior to harvest, a common approach in sugarcane producing areas without a frost hazard.

Early[10] conducted an extensive review of the agricultural production function literature. The results of irrigation experiments for sugar cane production reported in the literature were compared using regression analysis on the reported data. The results of irrigation trials under controlled and field conditions were reported for the Philippine production environment. The controlled experiments accounted for 83.5% of yield variability and the field experiments accounted for 73.8% of yield variability. The combined use of water/rainfall variables alone accounted for 67.2% of yield variability. Sanderson[24] cited pioneer studies of water yield relationships with timed water inputs, Moore[19] advocated separate timed inputs of water by periods in growing season, and Hogg *et al*[16] used an effective pan factor as a measure of the irrigation water inputs to cane production in an analysis using stepwise regression on data from plantation records in Hawaii.

Cady and Fuller[7] suggested a new methodology for the calculation of orthogonal polynomial coefficients, Grimes[13] used the central composite rotatable design in production function analysis, and Laird and Cady[18] used successive backward elimination of variables in stepwise regression on several sets of input variables, one of which was based on intuition. Yaron[26] distinguished two types of water yield relationships. One was the total water yield relationship with fixed intraseasonal water distributions and the second was the relationship for flexible water inputs, which were in effect dated inputs. Reutlinger and Seagraves[22] included a probabilistic analysis of moisture deficit from precipitation records to predict added yield due to water inputs.

The increased utilization of systems analysis techniques in sugar industry

problem solving and increasing management effectiveness has indicated an increased need for farm production data analysis Paty[21] described management by objectives application to an integrated sugar field/factory company in Hawaii using a procedure of setting of objective, then assessing success periodically. Blaquier, *et al*[4] used the concept of an ecological zone to develop a master plan for use in the optimal sequencing of operations of an integrated sugarcane farm/mill estate in Argentina. Panol[20] developed yield models in order to predict sugar and cane production from farms as inputs to a factory using climatic and milling results from previous years and a variable for crop year in the Philippines. Preliminary results indicated that a different shutdown period may be more advantageous than currently used.

Bull and Tovey[6], in a simulation of plant physiological growth, photosynthetic production and water stress models illustrated the use of this technique to micro production problems. Guise and Ryland[14] used quadratic programming to improve the scheduling of production in Australina sugar mills. Ryland and Guise[23] developed an activity analysis to determine the optimum production period giving explicit treatment to cane quality over time and space to give an optimum production schedule. Sorenson and Gilheany[25] used simulation to test harvesting strategies and decision rules for a Caribbean sugarcane plantation.

Aste-Tonsman[1] determined optimal irrigation and harvest policies with a modification of the simplex linear programming logarithm allowing long run and short run decision making with detailed information maintained on the field conditions. Early[10] indicated the use of Crude Monte Carlo procedure for modelling the operation features of a sugarcane milling district in the Philippines. The research indicated the use of yield prediction equations for tonnage and rendement as a function of the year, age, rainfall in periods 1-30 and 31-60 days before harvest. The yield increments to irrigation applications in the dry season were expressed as sugar tonnage increments and obtained by multiple regression from field production data.

Several investigators have reported production function analyses for Philippine farms. Escober[11] cited that excessive rainfall in excess precipitation was the main factor influencing rendement yield of canes. Ferraris, *et al*[12] reported comprehensive experiments on the effects of varieties, month of planting and age at harvest on the yield at harvest. Significant interactions were recorded between any pair of the three variables. Specific recommendations for each combination of variables to avoid the sugar losses due to the decline in juice quality were suggested. Bouldin[5] reported multiple regression analyses on soil properties, varietal differences, climatic factors and fertilizer response data of the general polynomial type. The models accounted for 30 to 40% of yield variability, two rainfall periods were utilized. Caintic[8] reported survey results from one milling district using the Cobb-Douglas production function on farm unit basis with the area, water applied, nitrogen used, labor and animal time as the inputs. This analysis accounted for 95 to 97% of farm sugar production variability in that dry climatic zone.

MATERIALS AND METHODS

The general procedure employed in the analysis of the farm production records was to first use stepwise multiple regression consecutively on available general records, climatic variables, and detailed farm production records. This type of analysis plus the use of intuitive judgement was then used to select the important variables that would be used in later regression analysis as independent variables in the yield component production functions. Once these important variables were identified, important distinctly identifiable categories of crop, month of planting, and age of harvest were selected as the basis of detailed multiple regression.

A survey of field production records from the Calamba Milling District on the Island of Luzon in the Philippines was limited to the two most commonly grown varieties, one which currently occupied the majority of the land, but was rapidly declining in acreage, and another which was rapidly increasing in acreage and was expected to be the primary variety in the forthcoming time span of 3 to 5 years. This data represented a rather large heterogenous sample of inputs and production data from an area of nearly 4000 hectares. In addition, a sample of data was obtained from one medium sized farm with a single management, data which were relatively homogeneous. In addition, climatic data were collected from nearby meteorological stations for the purpose of correlations and detailed enumeration of the important inputs to sugarcane production.

Once this analysis was completed, specific production functions were then available for the prediction of rendement and tonnage yield whose product was sugar yield. These were necessary input functions for production scheduling in the synchronization of production and milling operations.

RESULTS

A survey of field production records from the Calamba Milling District included 1657 crop records for an eight-year period. The record was limited to two varieties CAC 57-11 and PHIL 56-226, which were the two most frequently grown varieties in the district in terms of total area occupied.

Stepwise multiple regression was applied to the record without rainfall input variables. Table 1 indicates the order of addition of the variables and the coefficient of determination for the yield components, rendement (PS/TC) and tonnage (TC/HA). All eight independent variables were included in the regression and the regression equation accounted for 28.0 and 5.6% of the respective yield component variability.

Rainfall records for the corresponding eight years were utilized to determine the rainfall input amounts by 30 day periods after each crop was planted or ratooned and by 30 day periods before each crop was harvested. Seven 30-day segments were used at each end of the cropping seasons. Multiple regression analysis was used to

TABLE 1. Results of stepwise multiple regression analysis using field production data from Calamba Milling District for 8 independent variables, 1964 1972.

Independent variables	Yield components	
	PSTC	TCHA
Harvest year	1*	5
Hacienda	4	8
Field Size	3	7
Crop	7	1
Variety	5	4
Month planted/ratooned	8	6
Month harvested	2	3
Age at harvest	6	2
R^2 (field production data)	280	.056

* *Number indicates step at which corresponding variable entered the regression.*

determine regression coefficients for first and second order terms of each of the fourteen rainfall variables in Table 2. The regression equation was significant at the 1% level of probability for all three yield components of tonnage (TC/HA), rendement (PS/TC), and sugar (PS/HA), while the coefficients of determination for each yield component were 0.058, 0.375, and 0.271, respectively.

Solar radiation records from the University of the Philippines, Los Banos, College of Agriculture Weather Station were used to detail solar radiation amounts for the corresponding 30-day periods in thousands of gm-cal/cm^2. The results of multiple regression analysis for first and second order terms of each of these 14 radiation variables produced the results in Table 3. The corresponding coefficients of determination were 0.055, 0.399 and 0.302 for tonnage, rendement and sugar yields, respectively.

Daily records of sunshine duration, relative humidity, wind run, and mean temperature were obtained from the college weather station for the eight year period. These meteorological inputs were used in the Penman equation to calculate daily potential evapotranspiration (PET) for the district. The PET was summed for 30-day periods after planting or ratooning, and before harvest as was done for the rainfall and radiation inputs. Class A pan evaporation (CAP) records were summed for the same 30-day periods as well.

Stepwise multiple regression was conducted on the gross model as shown in Table 4. Seventy-one independent inputs were included in the regressions for the three yield components. The order of entry or removal of the variables was tabulated. The coefficients of determination were 0.095, 0.585, and 0.422 for tonnage, rendement, and sugar yield, respectively.

Early[9] reported multiple regression results for controlled experimental yields

TABLE 2. Multiple regressional analysis of overall rainfall-yield relationship using 14 rainfall variables

R^2				F ratio			N.DF	F	F
TCH	PSTC	PSHA	No. of Cases	TCHA	PSTC	PSHA	D.DF	0.95	0.99
0.058	0.375	0.271	1657	3.61**	34.8**	21.6**	28/1628	1.48	1.73

			Regression coefficients					
			TCHA		PSTC		PSHA	
	Mean	SD	1st order	2nd order	1st order	2nd order	1st order	2nd order
TCHA	76.8							
PSTC	1.71							
PSHA	125.8							
R1	1.86	3.73	−1.016	−0.056	−0.032**	0.002**	−2.957**	0.041
R2	2.39	4.37	2.045	−0.129	−0.024**	0.002**	0.136	−0.065**
R3	3.55	5.07	−0.615	−0.036	−0.007**	0.001**	−0.162	−0.046
R4	5.16	5.50	−0.039	−0.012	−0.021**	0.001**	−1.632**	0.073**
R5	7.31	5.30	−0.004	−0.026	−0.006**	0.001**	−0.994**	0.039
R6	8.61	4.48	−0.073	−0.025	0.003	0.0004**	−1.948**	0.059**
R7	8.67	4.26	−1.156	−0.011	−0.013**	0.001**	−2.483**	0.060**
R8	5.06	4.45	−1.249**	−0.065**	−0.024**	0.001**	−1.938**	0.084**
R9	5.90	5.67	−0.628	0.052	−0.018**	0.001**	−1.438	0.072**
R10	6.39	5.00	−0.335	0.046	−0.018**	0.001**	−1.365**	0.086**
R11	7.99	4.63	−0.399**	0.132**	0.015**	−0.001**	−1.041**	0.057**
R12	9.39	4.75	−2.458**	0.126**	0.019**	−0.001**	−2.253**	0.015**
R13	8.83	4.49	−1.723**	−0.018	0.030**	−0.001**	1.867**	−0.006
R14	6.58	4.99	1.760**	−0.056	0.017**	−0.001**	3.976**	−0.129**
Constant			94.16		1.725		160.47	

* *Significant at 5% level of probability*

** *Significant at 1% level of probability*

TABLE 3. Multiple regression analysis of overall radiation-yield relationship using 14 radiation variables

R^2				F ratio			N.DF		
TCHA	PSTC	PSHA	No. of Cases	TCHA	PSTC	PSHA	D.DF	F 0.95	F 0.99
0.055	0.399	0.302	1657	3.35**	38.6**	25.1**	28/1628	1.48	1.73

	Mean	Regression coefficients					
		TCHA		PSTC		PSHA	
		1st order	2nd order	1st order	2nd order	1st order	2nd order
TCHA	76.8						
PSTC	1.71						
PSHA	125.8						
R1	12.03	10.80**	−0.422**	−0.036**	0.002**	8.467**	−0.270**
R2	12.95	16.13**	−0.658**	−0.066**	0.003**	12.854**	−0.464**
R3	13.48	19.91**	−0.732**	−0.105**	0.004**	21.614**	−0.784**
R4	13.42	21.03**	−0.841**	−0.167**	0.007**	15.160**	−0.522**
R5	12.57	19.16**	−0.735**	−0.045**	0.002**	15.378**	−0.581**
R6	11.72	2.15	0.017	0.090**	−0.004**	−3.072	0.290
R7	10.97	11.17**	−0.379	−0.040*	0.002**	3.757	0.101
R8	9.96	1.40	−0.012	−0.020	0.003**	5.489	−0.175
R9	10.22	− 8.88	0.432	0.243**	−0.012**	9.876**	−0.506**
R10	10.29	−20.09**	0.934**	0.072**	−0.002	−21.597**	0.983**
R11	10.43	−13.56	0.706	−0.176**	0.009**	−6.320	0.261
R12	10.71	12.02	−0.518	0.094**	−0.003**	16.729**	−0.835**
R13	11.56	1.28	−0.098	0.91**	−0.004**	12.387**	−0.692**
R14	12.95	1.57	−0.139	0.249**	−0.011**	19.483**	−0.939**
Constant		−429.13		0.344		−578.95	

* *Significant at 5% level of probability*

** *Significant at 1% level of probability*

TABLE 4. Results of stepwise multiple regression analysis using field production data from Calamba Milling District for 71 independent variables, 1964 1972.

Independent variables	Yield components PSTC	TCHA	PSHA
Harvest year	20	19	27
Hacienda	9	65	50
Field area	3	16	16
Crop	43	1	1
Variety	17	6	8
Month ratooned/planted	71	36	42
Month harvested	5	39	11
Age of harvest	13	15	29
Total irrigation applied	69		18
Number of irrigation	70		68
Rainfall total		35	36
Radiation total	47	58	
Pan evaporation total	46	49	2
Penman PET total			55
Rainfall 1-30 days after plant/ratooned	(1)	(2)	73
31-60 " " " "	67	28	30
61-90 " " " "	28	74	49
91-120 " " " "	44	26	64
121-150 " " " "	64	38	(3)
151-180 " " " "	48	52	58
181-210 " " " "	36	9	15
Rainfall 1-30 days before harvest	1	(4)	34
31-60 " " "	2	21	31
61-90 " " "	7	69	26
91-120 " " "	60	20	33
121-150 " " "	33	62	41
151-180 " " "	12	10	9
181-210 " " "	10		
Solar Radiation 1-30 days after plt/rat.	38	5	5
31-60 " " "	51	55	47
61-90 " " "	66	61	(5)
91-120 " " "	14	(6)	63
121-150 " " "	37	7	66
151-180 " " "	39	29	75
181-210 " " "	63	23	22
Solar Radiation 1-30 days before harvest	54	50	72
31-60 " " "	23	45	40
61-90 " " "	57	8	6
91-120 " " "	8	70	51
121-150 " " "	(7)	34	54
151-180 " " "	6	14	12
181-210 " " "	18	41	24
Penman PET 1-30 days after plt/rat	50	30	38
31-60 " " "	40	54	48
61-90 " " "	49	57	14
91-121 " " "	72	47	62
121-150 " " "	(8)	71	69
151-180 " " "	56	11	67
181-210 " " "	27	(9)	4

Table 4 cont'd.

Independent variables	Yield Components PSTC	TCHA	PSHA
Penman PET 1-30 days before harvest	55	51	(10)
31-60 " " "	22	46	3
61-90 " " "	58	31	56
91-120 " " "	21		52
121-150 " " "	45	64	76
151-180 " " "	19	18	21
181-210 " " "	24	32	35
Rainfall 1-20 days after plt/rat sqd.	16	32	35
31-60 " " "	42	27	20
61-90 " " "	73	4	10
91-120 " " "	34	25	65
121-150 " " "	29	17	61
151-180 " " "	35	53	57
181-210 " " "	30	43	74
Rainfall 1-30 days before harvest sqd.	53	72	44
31-60 " " "	11	60	37
61-90 " " "	15	66	45
91-120 " " "	61	22	23
121-150 " " "	32	63	19
151-180 " " "	25	44	46
181-210 " " "	52	42	43
Rainfall totla squared	62	48	7
R^2 (Field production results)	.585	.095	.422

(1) Variable entered step 26; removed step 59; re-entered step 74.
(2) Variable entered step 3; removed step 37.
(3) Variable entered step 17; removed step 32; re-entered step 60.
(4) Variable entered step 56; removed step 67.
(5) Variable entered step 39; removed step 59; re-entered step 70.
(6) Variable entered step 12; removed step 33; re-entered step 68.
(7) Variable entered step 4; removed step 31; re-entered step 68.
(8) Variable entered step 41; removed step 65; re-entered step 75.
(9) Variable entered step 2; removed step 13; re-entered step 24; removed step 59; and re-entered step 75.
(10) Variable entered step 13; removed step 53; re-entered step 71

and field trials. The following Table 5 summarized the yield prediction capability of the stepwise regression analysis of the results from the controlled experiments, the field trials, and the field production records. Agronomic variables included the crop and variety, treatments were represented by integer dummy variables, water variables were rainfall amounts, and irrigation variables were quantities for specified durations in the cropping period. The comparison of regressions indicates that the yield variability accounted for increases when all four variable types were included as input variables. The tonnage predictability was the most variable, ranging from 10 to 90 percent, while the rendement and sugar yield predictability were in the range of 43 tc 82 and 67 to 89 percent, respectively. Rainfall and irrigation alone accounted for half of two thirds, 54 to 67 percent, of yield variability on a combined basis in the analysis of experimental and field irrigation trials.

Multiple regression analysis was used to obtain water-yield relationships for updating tonnage and rendement for the simulation analysis. The independent variables used were rainfall 1 to 30 days before harvest, rainfall 31 to 60 days before harvest, the age of the crop and an integer variable for the type of rainfall year experienced by the crop and reflecting the accumulated rainfall quantity. The second order terms for the two rainfall variables were included. The regressions were selected for all combinations of crop (plant or ratoon), variety (CAC 57-11 or PHIL 56-226), and month of planting or ratooning (October-June). The results are shown in Table 6.

TABLE 5. Summary of yield production capacity of stepwise multiple regression analysis with agronomic, treatment, water, and irrigation variables.

Experiment		Percent yield variability explained for yield component			Variable type included			
		PSTC 1/	TCHA 2/	PSHA 3/				
(1)	Experiment Station	43.0	89.0	83.5	A 4/	T 5/	W 6/	1 7/
(2)	Field Trials	82.1	68.5	73.8	A	T	W	1
(3)	Combined (10)& (2)	53.8	66.8	67.2			W	1
(4)	Field Prod. Records (8)	58.5	9.5	42.2	A		W	1
(5)	Field Prod. Records (9)	42.9	40.9	44.1	A		W	1

1/ Piculs sugar per ton cane
2/ Tons cane per hectare
3/ Piculs sugar per hectare
4/ Agronomic variables
5/ Treatment variables
6/ Water as rainfall variables
7/ Irrigation input variables
8/ Field production data — Calamba District
9/ Field production data — La Carlota District

The number of cases available for regression was insufficient in seven crop, variety, month combinations. The statistical analysis of the data indicated that predictive capability of the equation for rendement, labeled PSTC, was highly significant at the 1 percent level of probability in eighteen crops variety, month combinations and significant at the 5 percent level of probability in three cases of the combinations. Of the cases where regressions were possible, twenty-one of twenty-five or 84 percent resulted in significant or highly significant regression equations.

For tonnage yield equations, only four were highly significant and two were significant according to the previous standard. This six of twenty-five was only 24 percent of cases of the combinations of crop, variety and month of planting or ratooning with significant or highly significant predictive capability.

Multiple regression analysis was used to obtained overall water relationships for the two rainfall variables and second order terms of the same rainfall variables with selection for yield response to irrigation water inputs for the simulation

TABLE 6. Results of multiple regression analysis of field production record from Calamba Milling District to obtain updated water-yield relationship with two water variables, age of crop, and rainfall year, selected for crop variety and month of planting or ratooning, 1964-1972.

Crop[1/]	Variety[2/]	Mo. of Plant ratoon[3/]	R^2 TCHA[4/]	R^2 PSTC[5/]	No. of Cases	F ratio TCHA	F ratio PSTC	D.F NUM DEN	F .95	F .99
1	1	1	0.02	0.51	217	0.69	35.8**	6/210	2.10	2.80
1	1	2	0.05	0.42	79	0.57	8.53**	6/72	2.24	3.11
1	1	3	0.10	0.52	41	0.65	6.03**	6/34	2.40	3.45
1	1	4	0.09	0.86	21	0.23	14.2**	6/14	2.85	4.46
1	1	5	0.21	0.59	23	0.72	3.92**	6/16	2.74	4.20
1	1	10	****	****	7	****	****	****	****	****
1	1	11	0.10	0.26	87	1.47	4.67**	6/80	2.22	3.09
1	1	12	0.05	0.36	132	1.14	11.7**	6/125	2.16	2.96
2	1	1	0.11	0.42	141	2.64**	16.2**	6/134	2.10	2.80
2	1	2	0.01	0.57	101	0.17	21.1**	6/94	2.20	3.03
2	1	3	0.25	0.43	121	6.17**	14.1**	6/114	2.19	2.99
2	1	4	0.26	0.36	84	4.56**	7.08**	6/77	2.23	3.11
2	1	5	0.24	0.38	21	0.73	1.43	6/14	2.85	4.46
2	1	10	****	****	0	****	****	****	****	****
2	1	11	0.22	0.47	37	1.38	4.46**	6/30	2.42	3.47
2	1	12	0.09	0.36	95	1.38	8.27**	6/88	2.21	3.04
2	1	1	0.28	0.18	74	4.40**	2.41*	6/67	2.24	3.12
1	2	2	0.02	0.16	87	0.33	2.46*	6/80	2.22	3.09
1	2	3	0.20	0.03	60	2.18	0.32	6.53	2.28	3.17
1	2	4	0.44	0.56	33	3.41*	5.61**	6/26	2.47	3.59
1	2	5	0.65	0.94	16	2.81	22.7**	6/9	3.37	5.80
1	2	10	****	****	5	****	****	****	****	****
1	2	11	****	****	1	****	****	****	****	****
1	2	12	0.18	0.32	12	0.18	0.39	6/5	4.95	10.67
2	2	1	0.39	0.25	20	1.40	0.71	6/13	2.92	4.62
2	2	2	0.48	0.69	25	2.79*	6.76**	6/18	2.66	4.01
2	2	3	0.23	0.71	26	0.94	7.70**	6/19	2.63	2.94
2	2	4	0.37	0.64	25	1.77	5.33**	6/18	2.66	4.01
2	2	5	0.71	0.86	13	2.43	6.12**	6/66	4.28	8.47
2	2	10	****	****	0	****	****	****	****	****
2	2	11	****	****	1	****	****	****	****	****
2	2	12	****	****	4	****	****	****	****	****

1/ Crop 1 = plant, 2 = ratoon
2/ variety 1 = CAC 57-11, 2 = PHIL 56-226
3/ month 1 = January, 2 = February, etc.
4/ Tons cane per hectare
5/ Piculs sugar per ton cane
**** *An insufficient number of cases was available for regression analysis*
** *Significant at the 1% level of probability.*
* *Significant at 5% lelvel of probability.*

analysis. The results for selection by crop and variety, by crop, by variety and by crop, variety, combination categories alone and three month groupings of month of planting or ratooning are shown in Table 7.

A sample of field production data was obtained in the La Carlota Milling District of the province of Negros Occidental. It was a small record for one harvest

TABLE 7. Results of multiple regression analysis of field production records from Calamba Milling District to obtain overall water yield relationship with 14 rainfall variables, selected for crop variety and month of planting or ratooning category, 1964-1972.

Crop	Variety	Month of plant/ ratoon	R^2			No. of Cases	F ratio			DF NUM DEN	F .95	F .99
			TCHA	PSTC	PSHA		TCHA	PSTC	PSHA			
1	1	***	0.04	0.52	0.16	616	0.83	22.5**	4.04**	28/587	1.47	1.71
2	1	***	0.07	0.44	0.22	627	1.52*	16.9**	6.12**	28/598	1.47	1.71
1	2	***	0.35	0.29	0.32	291	5.13**	3.86**	4.35**	28/262	1.47	1.71
2	2	***	0.44	0.40	0.38	123	2.62**	2.26**	2.05**	28/94	1.60	1.92
1		***	0.04	0.38	0.15	907	1.19	19.6**	5.66**	28/878	1.47	1.71
2		***	0.06	0.38	0.19	750	1.78**	15.7**	6.08**	28/721	1.47	1.71
	1	***	0.05	0.48	0.32	1243	2.31**	40.7**	20.1**	28/1214	1.47	1.71
	2	***	0.36	0.24	0.36	414	7.71**	4.44**	7.57**	28/385	1.47	1.71
1	1	1,2,3	0.05	0.49	0.20	346	0.60	10.7**	2.79**	28/317	1.47	1.71
1	1	4,5,6	0.53	0.93	0.87	50	0.84	10.5**	4.96**	28/21	2.02	2.73
1	1	10,11,12	0.25	0.56	0.20	217	2.21**	8.42**	1.70*	28/188	1.47	1.71
2	1	1,2,3	0.09	0.50	0.22	395	1.36	12.8**	3.65**	28/366	1.47	1.71
2	1	4,5,6	0.53	0.54	0.45	121	3.75**	3.87**	2.67**	28/92	1.60	1.92
2	1	10,11,12	0.21	0.58	0.42	97	0.64	3.34**	1.77**	28/68	1.65	2.03
1	2	1,2,3	0.32	0.29	0.29	222	3.27**	2.88**	2.82**	28/193	1.47	1.71
1	2	4,5,6	0.72	0.83	0.59	53	2.51*	4.23**	1.25	28/24	1.95	2.59
1	2	10,11,12	****	****	****	15	****	*****	****	*****	****	****
2	2	1,2,3	0.51	0.53	0.46	70	1.51	1.62	1.27	28/41	1.75	2.21
2	2	4,5,6	0.79	0.85	0.78	45	2.18	3.29**	2.01	28/16	2.20	3.10
2	2	10,11,12	****	****	****	2	****	******	****	*****	****	****

* *Significant at the 5% level of probability*

** *Significant at the 1% level of probability*

*** *Month of planting/ratooning not used in selection for analysis*

**** *An insufficient number of cases was available for regression analysis.*

TABLE 8. Results of stepwise multiple regression analysis using field production data from La Carlota Milling District for 35 independent variables, 1968-1969

Independent variables	Yield Components PSTC	TCHA	PSHA
Crop	12*	3	6
Field Size	8	5	3
Nitrogen application rate	3	15	—
Phosphorus application rate	5(26)**	2	2
Potassium application rate	6	7	8
Total rainfall			
Age at harvest	4	19	
Month of harvest		4(20)	4
Soil Type	11	8	13
Irrigation availability	7	9	10
Occurrence of extraordinary events			
Variety	10(18)24		
Year			
Total Irrigation	13	1(18)	1(11)
Rainfall 60 days after planting/ratooning		6	
Residual rainfall	2	12	
Rainfall 60 days before harvest	16	21	12
Total rainfall squared	15(27)		9
Total irrigation squared	14	10	
Rainfall 60 days after planting/ratooning squared	17(25)	13	14
Residual rainfall squared	23	16	
Rainfall 60 days before harvest squared	19	11	7
Total water	21	17	5
Total water squared		23	
Total water 60 days after planting/ratooning	9(20)22	22	
Total water 60 days after planting/ratooning squared	1	14	
R^2 (field production data) =	.714	.703	.613

* *Number indicates step at which variable entered the regression.*

** *Number in parenthesis indicates step at which corresponding variable was removed from the regression.*

year and included only 44 crop records. The stepwise multiple regression analysis for the three yield components are shown in Table 8. Rainfall variables were rainfall 1-60 days after planting or ratooning, rainfall 1-60 days before harvest and residual rainfall occurring for the intervening period. The coefficients of determination were 0.714, 0.703, and 0.613 for rendement (PS/TC), tonnage (TC/HA) and sugar yield (PS/HA), respectively.

The simulation model for synchronization of field and factory operations requires the updating of the yield components rendement and tonnage. Updating equations were obtained by multiple regression analysis of yield as the dependent

variable on the independent variables, type of rainfall year, age of cane, rainfall in previous 30 days, rainfall in next 30 days. The equations are of the form:

$$Y = a_o + a_1 (YR) + a_2 (K) + a_3 (RF60BF) + a_4 (RF60BF)^2 + a_5 (RF30BF) + a_6 (RF30BR)^2$$

where

Y = rendement or tonnage yield
YR = characteristic rainfall year
K = age of cane in months
$RF30BF$ = rainfall 1 -3 days before harvest
$RF60BF$ = rainfall 31-60 days before harvest
a_o = regression constant
$a_1, a_2, a_3, a_4, a_5, a_6$ = regression coefficient

The regression wire selected for specific combinations of crop, variety and month of planting or ratooning. For two crops, two varieties and nine months of planting or ratooning, thirty-six regression equations were used for each yield component, rendement and tonnage. The detailed relationships used in the simulation are listed in the subroutines REND and TONN of the program listing (Early[10]).

Sample rendement and tonnage updating relationships are shown in Figures 1-6. For each figure two of the independent variables are held constant in representative values, while two of the independent variables are allowed to vary over representative values or integer levels, respectively.

In Figure 1 rainfall 1-30 days and 31-60 days before harvest were each held constant at 7.5 centimeters. Rendement and tonnage were plotted as linear relationships of the age of cane for rainfall characteristics year integer values 4, 6 and 8.

In Figure 2, rainfall 31-60 days before harvest was held constant at 7.5 centimeters and characteristic rainfall year was held at Type 6. Rendement and tonnage were plotted as curvilinear relationships of the rainfall 1-30 days before harvest for cane ages 9, 11, 13 and 15 months. Rendement decreased with increasing rain from 0.25 centimeters. Tonnage decreased to 17 centimeters of rain, then increased.

In Figure 3. rainfall 1-30 days before harvest was held constant at 7.5 centimeters and characteristic rainfall year was held at Type 6. Rendement and tonnage were plotted as curvilinear relationships of the rainfall 31-60 days before harvest for cane ages 8, 11, 13 and 15 months, Rendement increased throughout the 0-25 centimeter range of rainfall. Tonnage increased to a maximum at 20 centimeters, then decreased to further inputs of rainfall.

In Figure 4. rainfall 31-60 days before harvest was held constant at 7.5 centimeters and cane age at 12 months. Rendement and tonnage were plotted as curvilinear relationships of the rainfall 1-30 days before harvest for characteristic

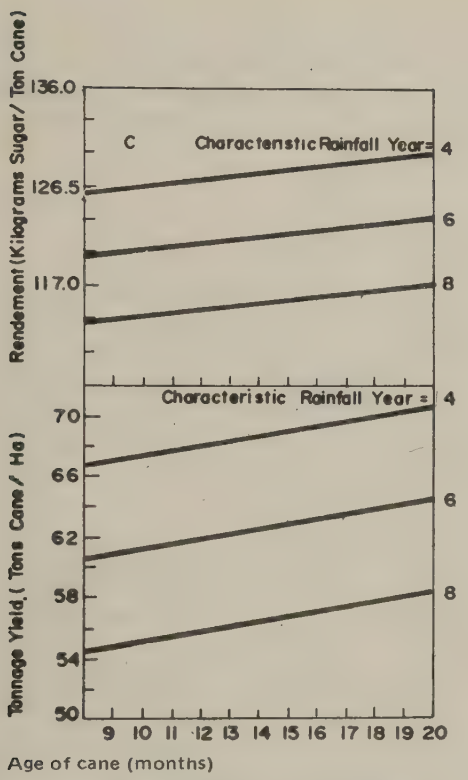

FIGURE 1. Relationship of age of cane at harvest and characteristic rainfall, year to rendement and tonnage yields for rainfall 1-30 days and 31-60 days before harvest each held constant at 7.5 centimeters.

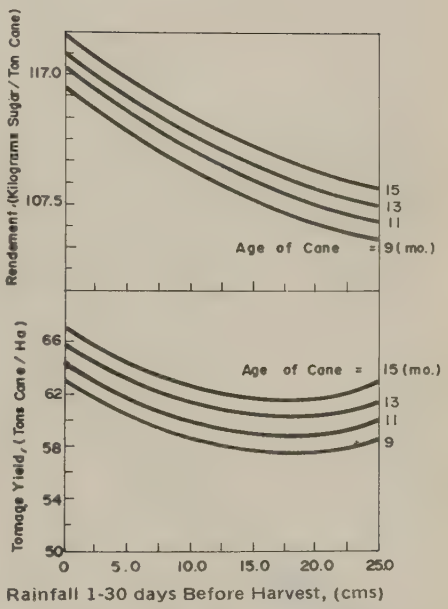

FIGURE 2. Relationship of rainfall 1-30 days before harvest and age of cane in months of rendement and tonnage yields for rainfall, 31-60 days before harvest held constant at 7.5 centimeters and characteristic rainfall year type 6.

rainfall integer values 4, 6 and 8. Rendement decreased nearly linearly throughout the range of rainfall inputs. Tonnage declined to a minimum at 25 centimeters of rainfall 1-30 days before harvest.

In Figure 5, rainfall 1-30 days before harvest were held constant at 7.5 centimeters and age of cane was held at 12 months. Rendement and tonnage were plotted as curvilinear relathionships of rainfall 31-60 days before harvest for rainfall characteristic years 4, 6 and 8. Rendement decreased to a minimum at 25 centimeters of rainfall. Tonnage increased to a maximum at 20 centimeters of rainfall, then declined for further rainfall 31-60 days before harvest.

In Figure 6, age of cane was held at 12 months and the characteristic rainfall year was type 6. Rendement and tonnage yield were plotted as curvilinear relation-

ships of rainfall 1-30 days before harvest for rainfall 31-60 days before harvest of 1, 3, 5, 7 and 9 centimeters. Rendement decreased nearly linearly for the range of 0 to 25 centimeters of rainfall in 1-30 days before harvest. Tonnage yield decreased to a minimum at 0.17 centimeters of rainfall, and gradually increased to 25 centimeters of rainfall in the 1-30 days period before harvest.

DISCUSSION AND CONCLUSIONS

The general scanning procedure for determining the important independent variables for consideration in production function modelling as an input to the synchronization of farm and factory operations has been outlined and demonstrated. The result has been the determination of update production functions for selected categories of crop, variety and month of planting or ratooning. The two predictive equations are for tonnage yield and rendement yield. The independent variables are

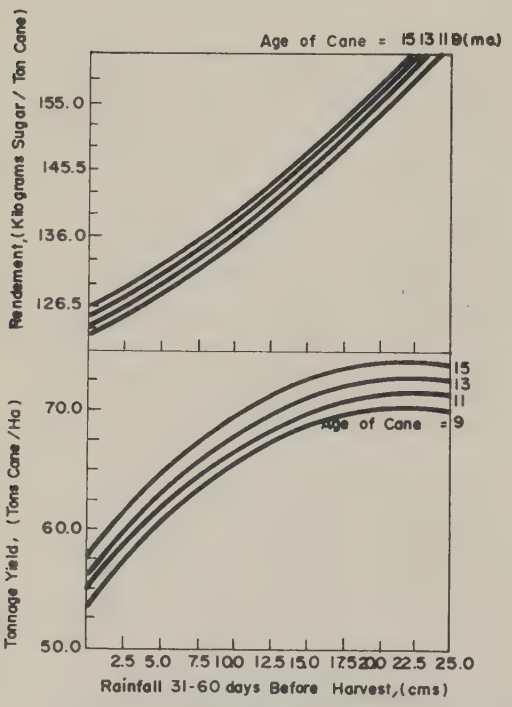

FIGURE 3. Relationship of rainfall 31-60 days before harvest and age of cane in months to rendement and tonnage yields for rainfall 1-30 days before harvest held constant at 7.5 centimeters and characteristic rainfall year type 6.

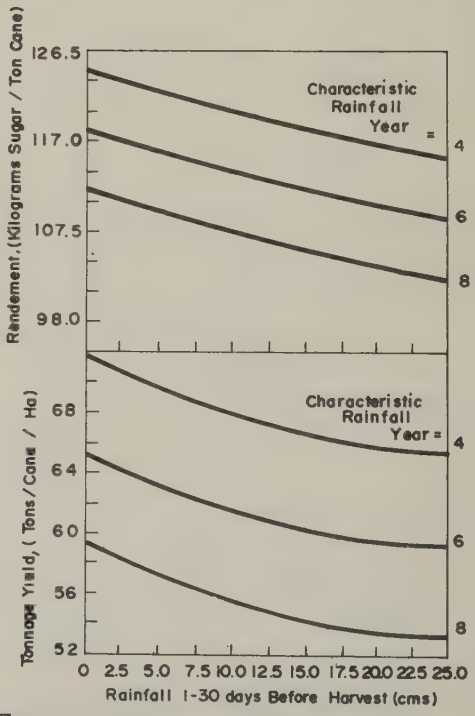

FIGURE 4. Relationship of rainfall 1-30 days before harvest and characteristic rainfall year to rendement and tonnage yields for 12-month age of cane and rainfall 31-60 days before harvest held constant at 7.5 centimeters.

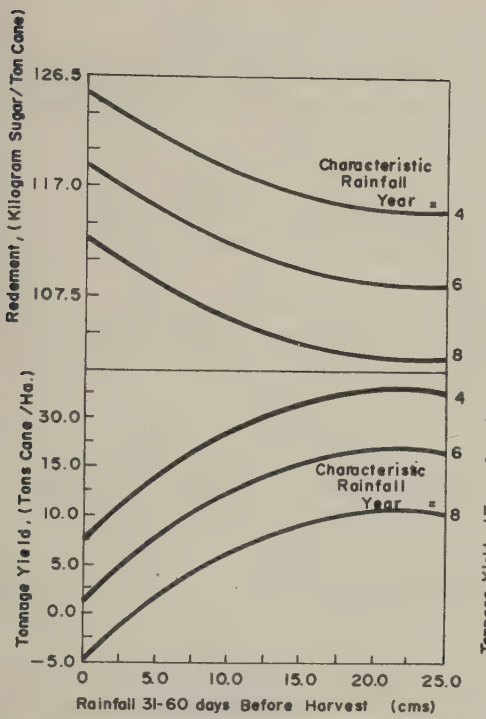

FIGURE 5. Relationship of rainfall 31-60 days before harvest and characteristic rainfall year to rendement and tonnage yields for 12-month age of cane and rainfall 1-30 days before harvest held constant at 7.5 centimeters.

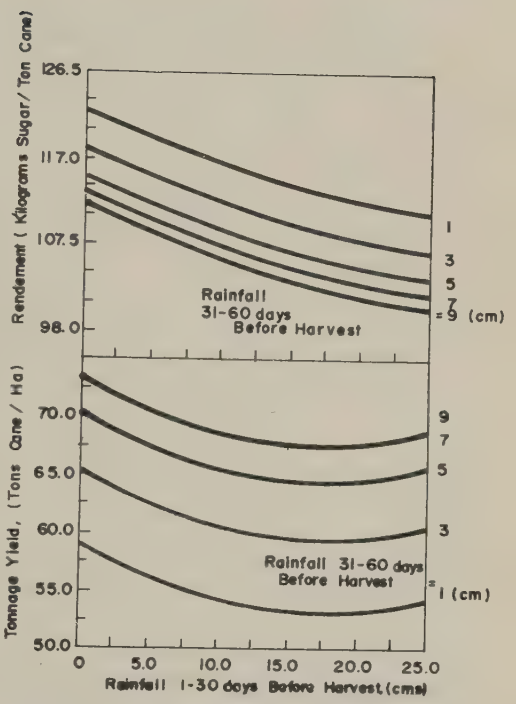

FIGURE 6. Relationship of rainfall 1-30 days and 31-60 days before cane harvest on rendement and tonnage yields for 12 month age of cane and type 6 characteristic rainfall year.

the age of the crop, the type of rainfall/climatic year, and two dated water input variables. These are the quantity of rainfall in the 1-30 day period before harvest and the amount of rainfall in the 31-60 day period before harvest. Each of these two water inputs was represented by a second order term as well.

Timed production functions for water inputs are essential to model the effects of irrigation and rainfall inputs to production. Water is an essential input for the growth of the crop and is, when applied or available in excess, an important factor hindering the ripening of cane. Forced ripening is best achieved through moisture control by irrigation timing although the alternative management option is nitrogen depletion. These update production functions are essential for modeling the sugarcane field/factory systems for the trial of operational policies and capacity constraints in simulation analysis. An additional potential practical use is in month to month yield forecasting. Further research is needed to attempt to improve the predictive capability of the production functions.

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ANALISIS DE DATOS DE PRODUCCION CON RESPECTO A FACTORES CONTROLABLES ,ENTRADAS AGRONOMICAS Y CONDICIONES AMBIENTALES PARA LA SINCRONIZACION DE OPERACIONES DE CAMPO Y FACTORIA

Alan C. Early

RESUMEN

La importancia de la aplicacion cuantitativa de varias entradas a la produccion de caña de azucar ha sido bien demostrada. Estas entradas incluyen la variedad, la cosecha, nivel de fertilidad, control de enfermedades e insectos, especialmente entre plantas y factores de densidad de poblacion, aplicacion de agua para satisfacer las demandas atmosfericas y eliminación de exceso de agua de la zona radicular. La importancia de poner en' optima secuencia las entrades y precisar el tiempo de aplicaciónes con respecto a factores ambientales ha recibido alguna atención. La importancia de precisar el tiempo y secuencia de las cosechas para alcanzar una producción optima de un distrito en determinado ingenio está alcanzando reconocimiento. Esta investigacion describe el procedimiento utilizado para la selección de factores significativos y el subsiguiente modelado de estos factores para predecir el rendimiento de caña de azucar y tonelaje con la edad de la cosecha y por los meses del año. Los principales factores determinados fueron entradas de lluvia mas irrigación en el periodo 1 a 30 dias y 31 a 60 dias antes de cosechar. Otros factores fueron el año en que se dio la cosecha. con respecto a un grupo integrado de factores climaticos, la edad de la caña al momento de cosechar, el mas de cosecha, la variedad y el tipo de cosecha. Se comparan los resultados de varios ensayos y un modelo en particular se analiza graficamente para mostrar los efectos de varios niveles de entrada'o factores sobre el rendimiento y tonelaje predecidos por el modelo. Se discute el papel de estos modelos para la sincronización de las operaciones de campo y factoria.

INFLUENCE OF K/N RELATIONSHIP IN FERTILIZATION ON POTASSIUM CONTENT AND ACTIVITY OF SOLUBLE INVERTASES IN SUGARCANE MERISTEM

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ABSTRACT

Potassium was applied to sugarcane using six K/N levels (from 0 to 2.5) with two back applications of N and P.

Potassium content and activity of acid and neutral soluble invertases in the meristem were studied. No significant differences were found among K/N levels or between back applications for invertases activity levels inspite of the significant differences found in potassium content. This seems to be connected with the high levels of potassium because even for K/N = O mean values higher than 5% for potassium were obtained.

The variation of the activity of both invertases during the development cycle of plant showed low levels at the beginning of the biological cycle and increased during the boom stage, and decrease of acid invertase and increase of neutral invertase at maturity.

INTRODUCTION

Invertases in sugarcane plays an important role in cellular mechanism, directing the utilization of carbohydrates for growth or storage (Sacher and Glasziou[10]). Hartt[7] was the first to state the potassium regulator role in catalyzed transformations of sugarcane invertases. Wilson[13] has stated different theories about the way monovalent cations, potassium in particular, can influence the stereostructure of enzymatic systems.

Evans and Wildes[6] stated that potassium is the only cation with adequate properties present in cells in sufficient concentration, to fulfill the univalent cation requirements of the great majority of those enzymes whose activity are dependent upon univalent cations.

In this paper the influence of different K/N levels in the activity of soluble invertases in three stages of sugarcane plant development was analyzed.

MATERIALS AND METHODS

An experiment was conducted on red ferralitic soil in June, 1975 using a sugarcane variety known as Ja 60-5 with a factorial design with 6 treatments represented by six different K/N levels (0; 0.5; 1.0; 1.5; 2.0 and 2.5) and two back applications of nitrogen and phosphorus (100kg/ha of N and P_2O_5, and 200 kg/ha of N P_2O_5) in a randomized block design with twelve treatments and four replications. Each replication covered an area of 192 m^2.

Nitrogen was applied as urea, fractioning it as follows: 1/5 at sowing time, 2/5 six weeks, and the rest 12 weeks after sowing. Phosphorus, as triple superphosphate was added at sowing time. Potassium, as muriate, was applied in halves at six and twelve weeks after sowing. When a sugarcane plant crop was harvested in April, 1976, the same amounts and types of fertilizers were applied in two halves at 2 and 8 weeks from harvesting in order to keep the same K/N levels under study.

Ripeness time was determined through the Factor Method (Armas and Amaral[4]). Samples were taken periodically in both cycles and % potassium was determined in meristem (bottom 5 cms of the spindle cluster) (Clements and Ghoth[5]) by flame photometry (AOAC[2]). Activity of soluble invertases and content of proteins were also determined in three stages of plant development.

TABLE 1. Soluble invertase activity levels at pH 5.5 and 7 (specific activity) in three stages of sugarcane plant development for different K/N relationship and back application fertilization.

K/N Levels	Back Application	Beginning of Boom Stage		End of Boom Stage		Maturation	
		pH 5.5	pH 7.0	pH 5.5	pH 7.0	pH 5.5	pH 7.0
0	1	1.79	0.78	5.93	2.26	2.11	11.38
0.5	1	3.01	0.63	7.22	3.01	1.36	10.40
1.0	1	2.72	0.50	6.40	3.51	2.89	11.04
1.5	1	3.29	0.64	4.49	1.36	3.63	13.25
2.0	1	1.94	0.93	4.36	3.30	1.54	8.34
2.5	1	1.78	0.54	5.28	2.81	1.84	8.76
0	2	3.37	0.86	5.06	1.14	1.80	10.82
0.5	2	1.92	0.39	7.37	2.52	1.69	8.39
1.0	2	3.65	0.74	4.85	2.19	1.33	10.30
1.5	2	3.71	1.08	6.47	4.25	2.67	13.51
2.0	2	2.67	0.75	3.45	3.02	1.00	9.86
2.5	2	2.31	1.10	6.22	2.83	2.90	10.58

F values

	pH 5.5	*pH 7.0*
Levels of K/N	*1.85*	*1.07*
Stages	*41.38***	*207.53***
Back Applications	*0.02*	*0.004*
L X BA	*0.46*	*0.71*

* *Significant at $P < 0.05$*
** *Significant at $P < 0.01$*

TABLE 2. Soluble invertase activity levels at pH 5.5 and 7 (specific activity) in three stages of sugarcane first ratoon development for different K/N relationship and back application fertilization.

K/N Levels	Back Application	Beginning of Boom Stage		End of Boom Stage		Maturation	
		pH 5.5	pH 7.0	pH 5.5	pH 7.0	pH 5.5	pH 7.0
0	1	2.91	2.70	9.82	3.72	4.90	8.05
0.5	1	1.31	1.71	10.47	2.96	3.11	9.29
1.0	1	2.09	2.31	9.15	3.38	1.42	10.36
1.5	1	1.86	2.12	8.00	4.20	3.02	11.25
2.0	1	1.61	1.98	7.25	4.47	2.50	11.41
2.5	1	2.27	2.23	10.11	5.01	2.51	12.00
0	2	2.48	2.22	8.77	3.61	2.87	9.60
0.5	2	3.21	2.32	9.29	3.93	4.83	11.98
1.0	2	3.11	1.79	10.24	3.07	2.90	10.74
1.5	2	3.68	1.93	9.84	2.96	1.56	9.83
2.0	2	2.63	2.41	8.96	4.07	3.15	12.01
2.5	2	1.72	2.37	10.19	3.87	1.75	10.14

	F Values	
Levels of K/N	pH 5.5	pH 7.0
Stages	1.17	2.04
Back Applications	231.00**	475.25**
L X BA	1.68	2.10
	1.74	1.98

* *Significant at $P < 0.05$*
** *Significant at $P < 0.01$*

Samples were prepared according to Alexander[1] and they were incubated for 30 minutes at 37°C with a 1% sucrose solution as substrate in buffers of pH 5.5 and pH 7.0.

Specific activity (units of activity/mg of protein) was determined. (unit of activity = 10^{-8} moles/min of sucrose hydrolyzed at 37°C). Reducing sugars and proteins were determined using Summer[11] and Sutherland[12], respectively.

RESULTS AND DISCUSSION

Enzymatic activity mean values detected in every treatment in three stages of plant development and for plant and first ratoon crops, respectively, are shown in Tables 1 and 2.

Results (Table 1 and 2) evidenced the only existence of significant differences among the stages of plant development considered.

No significant differences were obtained either among treatments or between backs application of fertilization in spite of the different doses of potassium applied, so there was no variation due to different nutritional levels.

In Tables 3 and 4 are shown mean values for potassium percent, in meristem,

TABLE 3. Variation with age of meristem potassium % in sugarcane plant.

K/N Levels	Back Application	Age in months 2.7	3.7	4.8	6.2	7.3	8.5	$\bar{X}$
0	1	6.75	6.12	5.75	5.50	4.30	4.75	5.52
0.5	1	6.50	6.25	6.25	5.62	4.30	5.25	5.70
1.0	1	6.75	6.25	6.12	5.75	4.62	5.00	5.75
1.5	1	6.75	6.62	6.25	6.00	4.75	5.30	5.95
2.0	1	7.00	6.25	6.25	6.25	4.62	5.37	5.96
2.5	1	7.00	6.92	6.25	5.87	5.12	5.30	6.08
0	2	6.75	6.25	5.75	5.62	4.50	5.17	5.67
0.5	2	7.12	6.50	6.25	5.75	4.37	5.00	5.83
1.0	2	7.12	6.62	6.00	6.00	4.37	5.50	5.94
1.5	2	7.00	6.50	6.25	6.00	4.50	5.17	5.90
2.0	2	7.00	6.62	6.50	5.62	4.87	5.50	6.02
2.5	2	6.75	6.50	6.25	6.00	4.75	5.50	5.96
$\bar{X}$		6.87	6.45	6.16	5.83	4.58	5.23	

	F values
Levels K/N	*10.40***
Ages	*230.34***
Back Application	*1.03*
L X BA	*1.21*

Duncan Test

Levels K/N	*X*
0	*5.60 a*
0.5	*5.77 b*
1.0	*5.85 bc*
1.5	*5.93 cd*
2.0	*5.99 d*
2.5	*6.02 d*

* *Significant at $P < 0.05$*
** *Significant at $P < 0.01$*

Different letters denote significant differences at least for $P < 0.05$

for cane plant and first ratoon, respectively.

Either in plant or first ratoon, potassium decreased with age and increased according to increasing values of K/N levels. These increments become significant up to a K/N level of 1.5 for cane plant and to a K/N level of 2.0 for first ratoon. However, no significant differences were obtained for invertase activity as shown in Tables 1 and 2. Hatch *et al*[8] referred to the existence of an acid invertase in immature tissues and a neutral one in mature tissues.

In our studies both invertases were detected in meristem. This fact agrees with Alexander's work and with Risk and Normand[9] who found high concentrations of both invertases in the highest third of the stalk.

The variation in the activity of both invertases during plant development

TABLE 4. Variation with age of meristem potassium % in sugarcane first ratoon.

K/N Levels	Back Appli-cation	Age in months				$\bar{X}$
		3.1	5.6	7.9	9.8	
0	1	5.83	5.83	6.66	4.79	5.78
0.5	1	6.66	5.83	6.66	3.75	5.73
1.0	1	6.45	6.25	7.08	4.37	6.04
1.5	1	6.45	6.25	6.66	5.41	6.19
2.0	1	6.25	6.66	6.66	5.41	6.25
2.5	1	6.25	6.87	7.08	5.41	6.40
0	2	6.05	5.83	6.25	5.20	5.83
0.5	2	6.05	5.62	6.66	5.62	5.99
1.0	2	6.25	6.25	7.08	5.62	6.30
1.5	2	6.25	625	6.87	5.62	6.25
2.0	2	6.66	6.66	6.45	6.83	6.65
2.5	2	6.25	6.66	7.08	5.62	6.40
$\bar{X}$		6.28	6.25	6.77	5.30	

	F values
Levels K/N	*3.20***
Ages	*24.92***
Back applications	*2.00*
L X BA	*0.27*

Duncan Test

Levels K/N	$\bar{X}$
0	*5.81 a*
0.5	*5.86 a*
1.0	*6.17 ab*
1.5	*6.22 ab*
2.0	*6.45 b*
2.5	*6.40 b*

* *Significant at $P < 0.05$*
** *Significant at $P < 0.01$*

Different letters denote significant differences at least for $P < 0.05$

n meristem showed low levels at the beginning of the biological cycle, increase uring the boom stage and decrease in the acid along with increases in the neutral nvertase during ripeness. Armas[3] found a similar behavior in other sugarcane arieties and different ecological conditions.

Inspite of the dependence stated by Hartt[7] between potassium and invertase ctivity, no significant difference was detected among treatments with sufficient otassium levels.

A possible explanation to this situation is the high value for potassium found

in meristem, where even for K/N=0, it kept a high mean value of 5.60% (see Table 3) and this high concentration could have satisfied the requirements of this cation for invertases.

CONCLUSIONS

No dependence of soluble invertase activity with potassium levels was found in meristem notwithstanding that this element reached very high values even for K/N=0.

Variation in the activity of both invertases during the development cycle of sugarcane showed low levels at the beginning, increase in the boom stage, and an increase of the neutral and a decrease of the acid invertase at maturity.

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INFLUENCIA DE LA RELACION K/N EN FERTILIZACION SOBRE EL CONTENIDO DE POTASIO Y ACTIVIDAD DE LAS INVERTASAS SOLUBLES EN EL MERISTEMA DE LA CAÑA DE AZUCAR

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RESUMEN

El potasio fue aplicado a la caña de azucar usando 6 niveles de K/N (0 a 2.5) con dos fertilizaciones posteriores de N y P.

Fue estudiado el contenido de K y la actividad de las invertasas solubles, acidas y neutras, en el meristema.

No se encontraron diferencias significativas ni entre niveles de K/N ni entre las aplicaciones posteriores para niveles de actividad de la invertasa, a pesar de las diferencias significativas encontradas en los contenidos de K. Esto parece estar relacionado con niveles de K, porque aun para un nivel de K/N igual a 0, fueron obtenidos valores medios mas altos que el 5% para el K.

La variación de la actividad de ambas invertasas durante el desarrollo del ciclo de la planta, mostró bajos niveles al comienzo del ciclo biologico, incrementos durante la etapa de crecimiento rapido y disminucion de la invertasa neutral en la maduracion.

INFLUENCE OF K/N RELATIONSHIP IN FERTILIZATION UPON SOME FOLIAR INDICATORS AND YIELDS OF SUGARCANE

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ABSTRACT

Potassium was applied to sugarcane using six K/N levels (from 0 to 2.5) with two back application of N and P to study the behavior of green weight, moisture, nitrogen, phosphorus index, total sugars and KH_20 using leaves 3,4, 5 and 6 as indicator tissue.

In general, increasing N/K level up to unity significantly increased green weight and moisture grant and significantly decreased total sugars. KH_20 showed significant increments up to K/N value . . nitrogen and phosphorus did not show significant change.

Sugar yields showed significant differences in cane plant crop up to K/N value of unity and in the first ratoon crop, up to 1.5.

High or medium correlations between potassium and yields were obtained in the different stages of plant development. K/N relationship behaved very much alike in some stages showing very high correlation coefficients.

INTRODUCTION

Potassium was one of the first mineral elements identified as essential for plant growth by Buner and Lucamus in 1866 (Morard[12]). Since then a great deal of papers has been written showing potassium as the only univalent cation essential in higher plants nutrition where it is also the most abundant. Many of those papers have shown the intimate relationship of potassium with almost every aspect of plant physiology. A multiplicity of functions has been attributed to potassium but the mechanisms of its action are still unknown.

Potassium is very important for sugarcane plant and there are many reports of its effect upon yields (Aloma *et al*[1], Fritz[9], Humbert[10], Samuels and Landrau[13, 14]). Armas[4] has found that not only potassium but also N/K relationship is important to assure a proper plant development.

In the present work the effect of different K/N levels were studied on some sugarcane indicator tissues and their correlation with yield.

MATERIALS AND METHODS

In June, 1975, a randomized complete block design experiment with 12 treatments and four replications was conducted on red ferralitic soil using the sugarcane variety Ja60-5. The treatments were arranged in factorial.

Six K/N levels were used, 0; 5; 1.0; 1.5; 2.0 and 2.5 with two different blanket applications of N and P (100 kg/ha of N and P_2O_5 and 200 kg/ha of N and P_2O_5).

Each replication covered an area of 192 m^2.

Nitrogen using urea (46% N) was applied in 3 doses with 1/5 of the amount at sowing time; 2/5 six weeks later, and the rest of it 12 weeks after sowing. Phosphorus as triple superphosphate (46% P_2O_5) was applied at sowing time.

Potassium, as muriate (60% K_2O) was applied in two equal doses at 6 and 12 weeks after sowing.

In order to keep the K/N levels under study under ratoon condition, the same amounts of fertilizers were applied after harvesting in April, 1976 with one half at two weeks and the rest, six weeks later.

In both cycles studied, samples were taken periodically (6 in plant and 4 in first ratoon) using leaves no. 3, 4, 5 and 6. Green weight, moisture content, primary index, nitrogen, phosphorus index and KH_2O were determined in the samples according to Clements' Crop-logging techniques (Clements[7,8]) using Rapid Analytical Methods of HSPA described by Clements[6].

Ripening stage was determined using the Factor Method (Armas and Amaral[5]) and yields, by stalk-weighing and sugar laboratory analysis (Spencer and Meade[15]).

RESULTS AND DISCUSSION

The analysis of variance showed significant differences ($P < 0.01$) for each K/N level in green weight, moisture and KH_2O, either in plant or ratoon. The primary index also showed significant difference but only for plant cane data.

The two blanket applications of N and P showed significant difference ($P<0.05$) in KH_2O only in plant cane. N and P values did not show significant difference even between levels.

Significant differences ($P<0.01$) were obtained between cycles for all indicators except for phosphorus index, which showed a diminishing trend with age in the plant cycle but remained almost at constant level in ratoon.

All interactions analyzed were not significant.

Table 1 shows mean values for each indicator under study and Duncan Test

results for every K/N relation.

In general, increasing K/N values increase green weight, moisture and potassium of leaf sheaths and decrease the primary index.

As a general rule, there are no significant variations when K/N levels are higher than unity, except for KH_2O, where significant increments were observed up to K/N value of 2.

TABLE 1. Foliar mean values obtained with different K/N levels of fertilization.

K/N Relationship	Green Weight (g)	Moisture (%)	N (%)	Total Sugars (%)	KH_2O	P Index
			Cane Plant			
0	361 a	79.1 a	1.91 a	11.96 a	0.27 a	0.10 a
0.5	369 ab	79.2 ab	1.91 a	11.53 ab	0.29 a	0.10 a
1.0	371 abc	79.7 abc	1.90 a	10.80 bc	0.35 b	0.09 a
1.5	382 bc	80.2 bc	1.88 a	10.92 bc	0.34 b	0.10 a
2.0	387 c	80.2 bc	1.91 a	10.83 bc	0.37 bc	0.09 a
2.5	386 c	80.3 c	1.91 a	10.34 c	0.40 c	0.09 a
			First Ratoon			
0	333 a	78.3 a	1.91 a	9.95 a	0.25 a	0.08 a
0.5	341 ab	78.3 a	1.93 a	9.90 a	0.32 b	0.06 a
1.0	355 bc	78.8 ab	1.91 a	9.62 a	0.35 bc	0.08 a
1.5	357 bc	79.4 b	1.91 a	9.67 a	0.37 c	0.08 a
2.0	359 c	79.1 b	1.90 a	9.72 a	0.38 cd	0.08 a
2.5	364 c	79.3 b	1.91 a	9.58 a	0.43 d	0.08 a

Different letters denote significant difference at least for $P < 0.05$

Ratoon results are very much alike those of plant cane data.

Agricultural and sugar yields at maturation showed significant difference only for different K/N levels. Mean values are shown in Table 2.

Table 2 shows no significant difference for yields K/N levels higher than 0.5, although for K/N = 1 there was an increment of 3.8 t cane/ha. Significant increments were obtained in ratoon for K/N levels up to 1.5.

Sugar yields showed significant increments for K/N value up to unity in plant, and up to 1.5 in ratoon.

Several foliar indicators (green weight, primary index and potassium of leaf sheaths) showing significant differences among treatments in three different stages

of the plant development (beginning and end point of boom stage and maturation) were submitted to correlation analysis also.

TABLE 2. Mean yields obtained with different K/N levels in fertilization.

K/N Relationship	t Cane/ha		t Sugar/ha	
	Plant	Ratoon	Plant	Ratoon
0	81.5 a	82.4 a	11.50 a	12.46 a
0.5	91.2 b	88.5 ab	12.69 ab	13.30 ab
1.0	94.8 b	94.6 b	13.67 c	14.08 b
1.5	95.7 b	107.0 c	13.61 c	16.72 c
2.0	97.5 b	113.8 c	13.87 c	17.30 c
2.5	96.6 b	109.5 c	13.94 c	16.73 c

Different letters denote significant differences at least for $P < 0.05$

In the case of green weight, low or medium positive correlations were obtained with sugar yields. The lowest correlation coefficient was at maturation stage.

Low negative correlation coefficients were obtained in general for primary index till the end of the boom stage and turned positive at maturation. The explanation of such a behavior is found in the physiological role of carbohydrates in plants, where they are used as energy source during plant growth and kept as reserve at maturation. This fact can also explain the statement of some authors as Lunin and Aughtry[11], in the sense that sometimes positive or negative correlations can be found between primary index and nitrogen depending upon the stage of plant development considered.

Potassium always showed higher medium positive correlation coefficients indicating its direct influence upon yields.

N/K relationships behaved in the same way, in some stages giving very high negative correlation coefficients.

These facts emphasized the physiological importance of N/K equilibrium assure good yields.

The experimental results obtained for the different foliar indicators used agreed with reports of other authors' for leaves 3, 4, 5 and 6 (Amaral, Pampin[2], Armas[3] and Clements[7]).

Inspite of the heavy application of potassium to some of the treatments, heavy concentration in leaf sheaths were not detected and as a rule values were

TABLE 3. Correlation coefficients between some foliar values in three stages of plant development and yields. Sugarcane plant and first ratoon.

	Ton Cane/ha					
	Beginning of Boom stage		End of Boom stage		Maturation	
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
Green weight	+0.52	+0.74**	+0.55	+0.65**	0.55	+0.48
Total Sugars	-0.57*	-0.25	-0.70**	-0.23	+0.31	+0.24
% K	+0.82**	+0.67*	+0.61*	+0.84**	+0.73**	+0.64*
N/K	-0.61*	-0.82**	-0.90**	-0.94**	-0.60**	-0.71**
	Ton sugar/ha					
Green Weight	+0.51	+0.76**	+0.54	+0.64*	+0.42	+0.47
Total Sugars	-0.44	-0.36	-0.76**	-0.25	+0.21	+0.26
% K	+0.75**	+0.70**	+0.63*	+0.83**	+0.69*	+0.65*
N/K	-0.57*	-0.83**	-0.88**	-0.92**	-0.59*	-0.71**

* *Significant at $P < 0.05$*
** *Significant at $P < 0.01$*

below normal. First ratoon crop yields were somewhat better than sugar.

As a rule, the higher the K/N relationship the higher the yields obtained, between 0 to 2. Only for sugar/ha, K/N=2.5 showed a new increase for regular crop. These increases were not always statistically significant specifically for K/N values higher than 1.5 (see table 2).

The influence of different levels of potassium and the N/K relationship in the plant upon yields must be emphasized. These facts were evidenced by the correlation coefficient found.

CONCLUSIONS

Significant variations in green weight, moisture and total sugars were obtained with increasing K/N up to unity. For KH_2O, significant increments were obtained with K/N relationships up to 2, but sugar yields increased significantly with K/N

relationships up to 1 for cane plant and 1.5 for first ratoon.

Potassium levels and N/K relationship within the plant influenced yield. K/N in the ratio between 1 and 1.5 is recommended.

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INFLUENCIA DE LA RELACION K/N EN LA FERTILIZACION SOBRE ALGUNOS INDICADORES FOLIARES Y COSECHA DE CAÑA DE AZUCAR

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RESUMEN

El potasio fue aplicado a la caña de azúcar usando 6 niveles de K/N (desde 0 a 2.5) con dos aplicaciones posteriores de N y P para estudiar el comportamiento peso en verde, humedad, nitrogeno, indice de fosforo, azucares totales y KH_2O, usando las hojas 3, 4, 5, y 6 como tejidos indicadores.

En general, aumentando el nivel de K/N hasta uno, fue responsable de aumentos significativos en el peso en verde y la humedad y disminucion importante en azucares totales. KH_2O mostro aumentos significativos hasta valores de 2K/N, pero el N y el P no mostraron diferencias significativas.

La producion de azucares mostro diferencias significativas en las cañas plantas hasta valores de 1 K/N en el cultivo de caña soca de 1 hasta 1.5.

Fueron obtenidas correlaciones elevadas o medianas entre potasio y cosecha en los diferentes estados de desarrollo de la planta. La relacion K/N se comportó de forma muy parecida en varias etapas mostrando coeficientes de correlacion muy altas.

CALIBRATION OF COPPER IN SUGARCANE IN NORTHEAST BRAZIL

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ABSTRACT

Data from randomized blocks were utilized for the study of copper calibration of the soil and +3 leaf. The treatments used in the calibration did not receive the copper fertilization.

The correlation were determined by regression analysis, taking the copper content of the soil and the +3 leaf respectively as the independent variable for the soil and leaf and the relative yields as the dependent variable. The equation used was $Y = a + b/x$.

In the calibration of copper in the +3 leaf, the nutrient in nitric perchloric extract was analyzed by atomic absorption spectrophotometry. The correlation coefficient was not significant ($r = 0.29$). As preliminary information, it can be suggested that the critical level of copper in the +3 leaf is 6 ppm.

INTRODUCTION

Sugarcane is the most important crop in the northeastern region of Brazil. The area used for this crop in the states of Pernambuco, Paraiba and Rio Grande do Norte is approximately 460,000 hectares with an average production of about 54 tons of cane per hectare, as stated by Santos[1 3]. In 1977 sugarcane represented 58% for the income of the state of Pernambuco, according to the Brazilian Annual Statistics[1].

Sugarcane was originally located in the coastal area of the northeast region due principally to the proximity of shipping to the external markets and the consumer market of the larger cities. Then areas farther away from the coast were used in the expansion area to fulfill governmental programs. These area have a flat topography which make it possible to partially or totally mechanize production.

A great part of this virgin land recently consists of sandy soil of low fertility. The cane grown in this soil shows a very retarded development and always has visual symptoms of deficiencies of nutrients not supplied in the fertilizers.

The sandy texture, the low content of organic material and the low supply of copper in the soil, according to Horowitz and Dantas[6], and Gilbert[5], is responsible for the low content of copper available to the plants.

The visual symptoms of copper deficiency in sugarcane were first identified in Brazil by Fernandes[4] in a podzolic soil with a low nutrient supplying power, in the state of Pernambuco. The author later found the same symptoms in podzolic and podsolized soils of the extense area between the states of Alagoas and Rio Grande do Norte. The author recommended the application of cupric fertilizers for these soils, rates varying between 1.5 and 5 kilograms of elementary copper per hectare.

The use of methods to determine the availability of nutrients for the plants is the major objective of the research, and by extending the benefits, to the cane growers. It is through this type of information that fertilizers recommendation are made. Calibration studies with some macronutrients were done and good results were obtained. For sugarcane, Marinho and Albuquerque[10] affirmed that good correlations exist between the content of extractable P in the soil and cane yield. On the other hand, there is much that could be done with respect to the micronutrients, as the level of existing information still is very small.

Gilbert[5] affirms that the methods to extract copper from the soil are not entirely satisfactory and only approximate data can be expected. This same author stated that foliar analysis could present more consistent results. Horowitz and Dantas[6] studied copper in the soils of the coastal forest zone of Pernambuco. The authors analyzed total Cu and copper extracted by 2M HCl, 0, 10 N HCL, 0,5M acetic acid and 0,05M EDTA. Based in published data from other regions the copper content, total as well as extractable, was at a deficient level in 4 municipalities. They also stated that the 0.05M EDTA presented more consistent data and that 0.6 ppm of copper in the soils is a deficient level. In sugarcane, Marinho and Albuquerque[6] stated that the copper content above 0.7 ppm extracted by 0.10N HCL, did not respond to fertilization with this nutrient. The same authors further stated that 5 kilograms of elementary copper per hectare was the economical rate obtained.

With the implantation of the National Soil Fertility Program oriented by DNPEA of the Agricultural Ministry, the North Carolina 0.05N HCL + 0.025N $H2SO_4$ method to extract P and K from the soil began to be used by most of the analytical laboratories of the Northeast soils.

Because of the good correlation obtained for P in the soil and yield as a basic, and the possibility of using only extract calibration of copper in the soil for sugarcane was attempted. The data of foliar analysis (33 leaf) with yield is also studied to make a comparison between the two methods, so that a better method of evaluating the need for copper fertilizations would be defined.

MATERIALS AND METHODS

For the calibration of copper in the soil and in the +3 leaf. 27 data points

TABLE 1. Average yields (TCH) of the various treatments in the 9 localities studied, with their respective analysis of variance, LSD (5%), by the method of Tukel and variation coefficients.

Treatments	O.D'Agua NC	S. Terezinha LVd	S. Helena PV_6	Treatments	S. Jose PV	U. Industria LVd	Massauassu LVd	S. Tereza PV	EECAC LVe	Treatments	S. Francisco $\Delta 2d$
0 – 0 – 0	100.94	101.24	51.00	0 – 0 – 0	97.14	71.67	89.23	82.28	126.57	0 – 0 – 0	22,33
Δ260-100-216	127.53	123.90	87.67	Δ260-100-216	117.97	85.50	114.66	116.69	135.29	Δ120-300-240	88.66
□ 80-100- 70	108.38	107.58	68.67	□100- 80- 70	112,50	82.00	110.68	108.65	136.69	□ 60-150-120	79.66
260-100-216 +Cu pulveriz.	132.82	117.45	88,83	260-100-216 +Cu pulveriz.	131,03	90.33	113,60	112.64	133,95	120-300-240 +Cu pulveriz.	89.16
Δ260-100-216 +Cu (3 Kg/ha)	131.20	132.63	76.33	Δ260-100-216 +Cu (3 Kg/ha)	178,10	87.00	90.09	135.19	132,48	Δ120-300-240 +Cu (9 Kg/ha)	92.66
260-100-216 +FTE (100 Kg/ha)	134.44	121.41	82.33	260-100-216 +FTE (10 Kg/ha)	132,67	103,00	114.96	132.99	139,64	120-300-240 +FTE (30 Kg/ha)	86.66
80-100- 70 +Cu pulveriz.	110.43	113,37	76.83	100- 80- 70 +Cu pulveriz.	121.47	81.50	99.96	103.70	139,66	60-150-120 +Cu pulveriz.	84.66
□ 80-100- 70 +Cu (3 Kg/ha)	126.24		79.19	□100- 80- 70 +Cu (3 Kg/ha)	129.03	93.00	100.14	117.52	147.77	□ 60-150-120 +Cy (9 Kg/ha)	84.66
80-100- 70 +FTE(10 Kg/ha)	125.64	8.15	15.67	100- 80- 70 +FTE(10 Kg/ha)	117.33	103.17	106.79	109.49	141.40	60-15-120 +FTE(30 Kg/ha)	81.33
F	3,51**	3.76**	1,52	F	62,56	30.07	1.23	19.55	46,66	F	20.41**
LSD (%)	32.61	24.25	33,98	LSD (5%)	62,56	30.07	33 22	17.95	46,66	LSD (5%)	19,81
CV %	9.20	7.10	16,10	CV %	17,00	16.10	15,10	5,45	11,71	CV %	8.60

NC = Brown non-calcium
LVd = Association of Dystrophic Red-Yellow Latosol and Red-Yellow Podzolic.
PV_6 = Red-Yellow Podzolic.
PV = Association of Red-Yellow Podzolic and Hydromorphic Podzolic.
$\Delta 2d$ = Association of Dystrophic Quartziferous Sand and Dystrophic Red-Yellow Latosol
LVe = Eutrophic Red-Yellow Latosol
Δ = Treatments with Restitution Fertilization (NPK)
□ = Treatments with Economical Fertilization (NPK)

were obtained from 9 experiments, set up for other purposes in the states of Pernambuco, Paraiba and Rio Grande do Norte.

RESULTS AND DISCUSSIONS

Table 1, shows different results between treatments as well as between localities. The analysis of variance of the blocks taken as a group for one locality, show a

TABLE 2. Sugarcane yield (TCH) of the plots with and without copper, nutrient content in the soil and leaves from the plots without copper.

Captions	NPK + Cu	NPK – Cu	Soil Test Cu ppm	Foliar analysis Cu ppm	Localities (Sugar Mill)
□	127.03	132.30	1.3	11	Olho D'Agua–PE
Δ	133.60	132.82	1.4	11	Olho D'Agua–PE
Δ	114.36	130.27	1.0	14	Olho D'Agua–PE
Δ	132.50	132.00	1.0	6	S. Teresinha–PE
Δ	136.00	112.56	0.8	5	S. Terezinha–PE
□	128.70	98.75	0.8	14	S. Terezinha–PE
□	89.00	55.00	0.7	20	Sta. Helena – PB
□	88.50	60.00	0.5	15	Sta. Helena – PB
Δ	79.00	94.00	0.7	11	Sta. Helena – PB
Δ	154.50	134.00	0.7	6	Sao Jose – PE
Δ	169.30	111.40	0.7	5	Sao Jose – PE
Δ	210.50	108.50	0.7	6	Sao Jose – PE
Δ	188.00	102.00	1,8	14	U. Industria–PE
Δ	73.00	73.00	3.5	11	U. Industria–PE
Δ	75.00	81.50	2,7	15	U. Industria–PE
□	96.70	111.02	1.6	14	Massauassu–PE
□	96.54	128.46	1.5	19	Massauassu–PE
□	107.18	92.58	1.6	14	Massauassu–PE
Δ	134.10	113.14	0.6	3	Sta. Tereza–PE
Δ	136.38	107.95	0.8	6	Sta. Tereza–PE
Δ	135.10	11.00	0.7	5	Sta. Tereza–PE
Δ	124.49	135.11	1.0	11	EECAC – PE
Δ	135.75	134.29	1.3	14	EECAC – PE
Δ	137.20	136.49	1.6	11	EECAC – PE
□	97.00	85.00	0.7	5	S. Francisco–RN
□	100.00	98.00	0.6	5	S. Francisco–RN
□	82.00	77.00	0.9	5	S. Francisco–RN

Δ = *Treatments with Restitution Fertilization (NPK)*
□ = *Treatments with Economical Fertilization (NPK).*

significant difference of 1% probability for 5 localities, while for 4 localities, there is no statistical difference shown between treatments.

The CB 45-3 variety of average precocity was used, presenting its maximum vegetative development between 8 and 10 months. At this time, the soil is collected in the proportion of 8:1 for each plot. During the growing period, the plots that did not receive copper at the Sao Jose and Sta. Tereza Sugar Mills in RN, showed visual signs of copper deficiency similar to those described by Fernandez[4].

Soil and Foliar Calibration

The results of sugarcane yield in plots with and without copper, the copper levels in the +3 leaf, from the plots that did not receive copper at the localities tested, are shown in Table 2.

The calibration curves related to the copper levels in the soil and in the +3 leaf, and relative yields are shown in Figures 1 and 2. The adjustments were obtained by the regression analysis of the type $Y = a + b/x$. The correlation coefficients obtained were significant at the 99% probability level for the soil ($r = 0.60$ and were not significant for the +3 leaf ($r = 0.29$).

The separation of the copper levels, determined by the analysis, in groups, were obtained from the calibration curves. This procedure is presented in the recommendations of Cate and Nelson[3], in which the authors based the non-parametric association test that separates the graph area into four unequal quadrants. Waugh and Fitts[18] in turn, concluded that adequate test methods would place 90% of the results in the positive quadrants. A close examination of Figures 1 and 2 shows that 89% of the observations (24 points) are in the positive quadrants in the curve of copper in the soil, while only 81% of the observations (22 points) in the North, all in the Northeastern Region of Brazil. These experiments were conducted in Latosolic, podzolic and podzolized soil and quartziferous sands, according to the descriptions of Jacomine *et al*[8].

The experimental design used was randomized blocks with each treatments repeated three times in each area; these treatments are listed in Table 1. The plots consisted of 7 rows, each 10 meters long and spaced 1.3 meters apart. The CB 45-3 variety was used and the 3 central rows were harvested 15 months after the sugarcane was planted.

The leaf samples (+3 leaf according to Kuipjer) were collected from the 2 rows of the interior border, 15 leaves per plot, 3 to 4 weeks after the sugarcane was planted. In each plot, the soil samples were taken in the proportion of holes between the rows = 8:1, according to the recommendations of the S.A.S.A. Experiment Station 15, when the plants were in their maximum vegetative development (± 8 months old).

The North Carolina extractant was used to evaluate the copper content in the soils. This procedure consists of the copper extraction with HCl 0.05N +

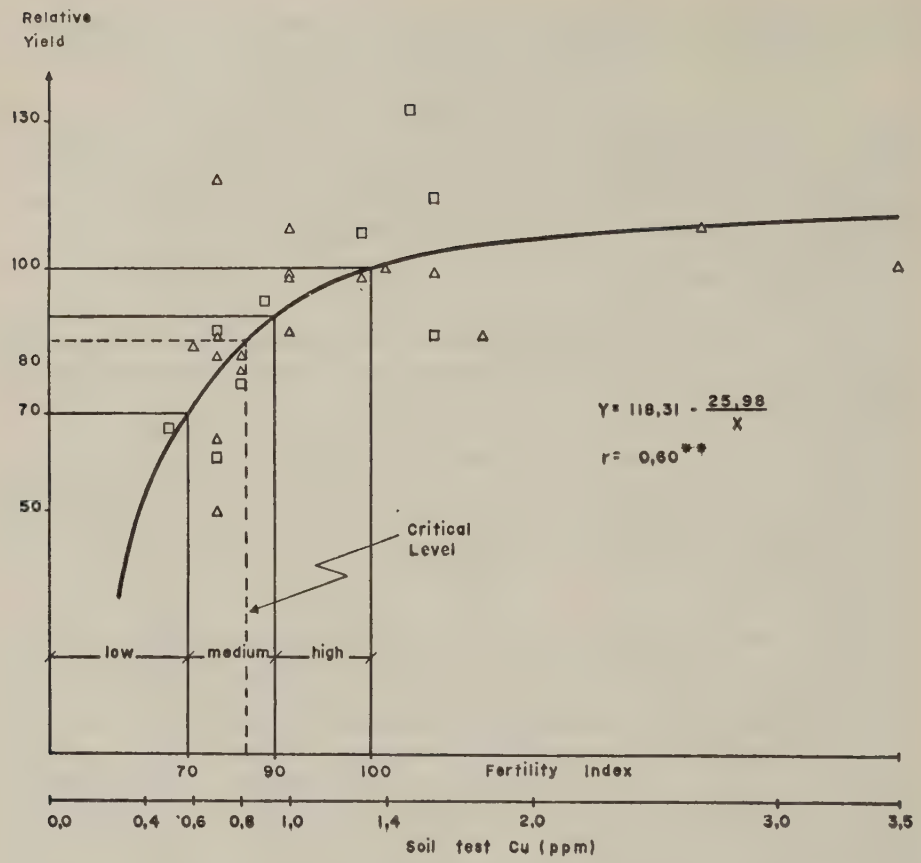

FIGURE 1. Relationship between soil test of Cu and relative yield of sugarcane

H_2SO_4 0.025N with a soil to extractant ratio fo 1:10, with 5 minutes shaking as described by Vettori[17]. For the leaves, approximately 20 cm. of the central part of the blades, without the principal vein, were oven dried with constant air circulation until they had a constant weight, ground in a Wiley type grinder, with a nr. 20 strainer and prepared nitric perchloric, according to the procedure described by Sarruge and Haag[16]. In both cases, the copper was determined by atomic absorption spectrophotometry with the model 460 equipment, following orientations of Perkin-Elmer[11].

The calibration curves of the soils leaves in the plots, that did not receive the nutrient, and the relative yield were calculated with the formula: RY = (yield with NPK and without copper/yield with NPK and with copper) x 100, see Table 2, taking the reciprocal of the copper content as an independent variable and the relative as a dependent variable.

To determine the critical level, the recommendation of the largest presence of

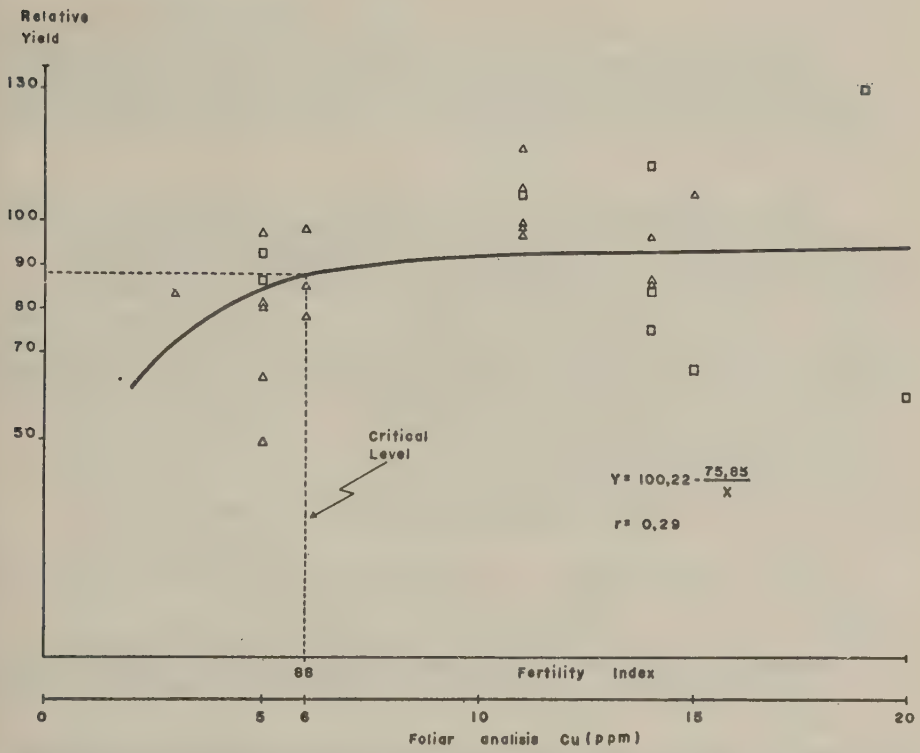

FIGURE 2. Relationship between foliar analysis of Cu and relative yield of sugar cane.

observations in the positive quadrants proposed by Cole and Nelson[3] was used.

The calibration curve of the copper in the soil (Figure 1) in the first place presents the identification of the critical level of copper extracted by North Carolina Extractor. The level is approximately 0.8 ppm. To somewhat improve the interpretation the procedures used by Marinho and Albuquerque[10] for P, and by Raij[12] for K, could be adopted. The authors used the data referring to 70 and 90% of the relative yield to better define the ranges of probable response. In this grouping, the index of 70 corresponds to approximately 0.6 ppm while the index of 90 ppm of Cu. The analysis of the bibliography, in respect to the copper levels in the soil that could produce nutritional deficiency, suggest the acceptance of the theories proposed by Horowitz and Dantas[6], and Marinho and Albuquerque[9]. Even though these values had been obtained from extractions with other solutions, still they are data sufficiently close to the results obtained.

The use of foliar analysis in making equations for the orienting parameters of fertilizers with nitrogen and micronutrients is supported by various researchers. For the cited macronutrient, the first studies carried cut in our region did not lead to conclusive results. Santos *et al*[14] did not register, in sugarcane, variations between the level of N% in the +3 leaf by provoked by kilogram of N per hectare or

by the yield. Above all, the authors have observed in field conditions, that the copper deficiency is sufficiently influenced by the humidity level of the soil. There are cases where the rain is sufficient to make the visual symptoms of deficiency disappear. For these cases, it is supposed that the foliar analysis would be affected by the deficient absorption of the nutrient.

The copper calibration curve in the +3 leaf, before reinforcing with the information given by Gilbert[5], even invalidates the method. The relation between the two values presented a correlation coefficient statistically non-significant ($r = -0.29$), proving the large dispersion of data. Only in the quality of preliminary information could the critical level of copper in the +3 leaf be identified as 6 ppm according to the interpretation methodology by Cate and Nelson[3]. This content correspond to 87% of relative yield and is sufficiently close to the levels that Humbert[7] (5 ppm) and Bowen[2] (4 ppm) stated to be the critical level respectively for the 3, 4, 5, 6 and TVD leaves.

CONCLUSIONS

Completing the discussion of the results obtained, the following conclusions can be implied:

1. The method of soil analysis to evaluate the copper content and to stimulate the production, lead to more consistent results than the analysis of the +3 leaf.
2. The 0.05N HCL + 0.025N H_2SO_4 extractor furnishes results of soluble copper sufficiently similar to other methods. The possibility of making joint determinations of P, K and Cu seems to be an advantage.
3. The interpretation of soluble copper calibration leads to the definition of low (0 to 0.6 ppm), middle (0.61 to 0.9) and high (over 0.9 ppm) content.
4. Even without a determination of an economical dosage (only a levels), however, being a nutrient used indisciminately by the sugarcane procedures, a 5 and 2.5 Kg. of Cu per hectare respectively, can be recommended as the first ranges

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CALIBRACION DEL COBRE EN LA CAÑA DE AZUCAR EN EL NORESTE DE BRASIL

Marcos Aurelio C. dos Santos y Antonio Fernando de Sobral

RESUMEN

Fueron utilizados 27 informes de bloques randomizados para el estudio de la calibracion del cobre del suelo y de la tercera hoja. Los tratamientos usados en la calibracion fueron aquellos que no recibieron los nutrientes antes de la fertilizacion, la correlacion determinada por analisis regresivo tomando el contenido de cobre del suelo y de la tercera hoja respectivamente como una variable independiente para el suelo y la hoja y tomando las cosechas relativas como variables dependiente.

La ecuacion usada fue $y = a + b/x$.

En la calibracion del cobre en el suelo fue usada la formula, 0,05, N HCI + 0,025 N H_2SO_4 y el coeficiente de correlacion ($r = 0.60$) fue significativo al 99% de probabilidad.

Usando valores de produccion relativa como criterio para la separacion de los grupos de cobre en el suelo, fueron establecidos los limites siguientes: el bajo de 0 a 0.6 ppm; el mediano de 0.61 a 0.9 ppm. y el alto, arriba de 0.9 ppm.

En la calibracion de cobre en la hoja N^o3 fueron analizados los nutrientes en extracto nitrico perclorico por espectrofotometria de absorcion atomica.

El coeficiente de correlacion no fue significativo ($r = 0.29$). Como informacion preliminar se puede sugerir de que el nivel critico del cobre en la hoja + 3, es 6 ppm.

SALINITY EFFECT IN SUGARCANE RESPONSE TO NITROGEN FERTILIZATION

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ABSTRACT

An experiment using 5 rates of nitrogen (180, 250, 320, 390 and 460 kg/ha) and 5 harvesting ages (12.3, 15.5, 20.0, 23.3 and 26.5 months) was conducted to determine the response of sugarcane to nitrogenous fertilization when soil has high salinity. A factorial experiment was used with 4 replications and a control treatment.

The study was performed in the Chancay-Lambayeque valley in the northern coast of Peru, where more than 30% of the area has the salinity or drainage problem.

In this extremely arid region, alluvial soil is predominant, of recent profile development and without well defined horizons. Soil salinity varies from 2 to 8 mmhos/cm. Under these conditions it was learned that sugarcane yield did not increase with the application of high rates of nitrogen. However, it is necessary to use minimal rates of nitrogenous fertilizers which are a function of soil saline concentration. Besides, it was also found out that the cane and recoverable sugar yield were inversely correlated with soil salinity. Finally, it was also determined that the best age for sugarcane harvesting is when cane are 15.5 months.

INTRODUCTION

Sugarcane response to nitrogenous fertilization under soil salinity conditions has not been studied much. However, there is some information about other crops. For example, Hulsbos[4] found that the use of nitrogenous fertilizers seems to be justified even on a very saline soil when they are used with such plants that are highly tolerant to salts as barley, sweet clover and alfalfa. On the contrary, rice and wheat, which are less tolerant to salts, showed a slight increase in production when they were treated with N on slightly saline soil. On the other hand, Khalil *et al* [8] states that in spite of salinity, considerable yield increase can be obtained through increasing the fertility level by fertilization. Yields of corn and cotton increased sharply as N was applied at different salinity levels, but higher yields were obtained from applying N as salinity was decreased.

Considering the fact that there is a tendency to grow sugarcane in virgin saline areas or in saline areas where plants resistant to salinity have been grown before (rice, cotton, "gramalote") and also considering the fact that in Chancay-Lambayeque valley more than 30% of its irrigated area (90,000 ha) has saline soil (FAO[2]), then it is important to study nitrogenous fertilization on saline soils, with the aim of maximizing the productivity of salt-affected soil through fertilizer application.

The purpose of this study was to find out whether sugarcane grown on saline soil can be successfuly treated with high rates of nitrogenous fertilizers, as in normal soils (non-saline). Another reason for conducting the experiment was to analyze the effect of the different rates of nitrogenous fertilizers on sugarcane which was harvested at different ages, and find out the best age for harvesting.

MATERIALS AND METHODS

The experiment was performed in the field Zapote C-D (recently included as an agricultural area) that belongs to the Agricultural Cooperative Tuman, located in the northern arid coast of Peru (Chancay-Lambayeque valley). On the 22 of May 1974, cultivar H32-8560 was planted in plots of 450 m^2. The factorial design in completely randomized blocks was used. The factors to be studied were: 5 rates of N (180, 250, 320, 390 and 460 kg/ha), 5 harvesting ages (12.3, 15.5, 20.0, 23.3 and 26.5 months), with 4 replications and one plot without N which served as control for each harvesting age. Climate in this region has the following characteristics: there is an average annual precipitation of 28 mm, an average annual evaporation of 4.5 mm/day and an average temperature of 22°C.

Soils are alluvials (entisols) of recent profile development and without well-defined horizons, calcareous, clay loam to sandy clay loam textured. Salinity in the 0.60 cm layer varies from 2 to 8 mmhos/cm. Table 1 shows the results of a soil physical and chemical analysis taken from a representative plot.

Before each of the 5 harvests, 6 samples of burnt sugarcane were taken from each plot and they were mixed in the field to get only 3 compound samples for each plot to be analyzed in the laboratory. The analysis included: pol % (P.), fiber % (F.), reducing sugars % and humidity % cane in addition to brix % and purity % (Pu.) of absolute juice. On the basis of these values the recoverable sugar % (recov. sug. %) was obtained with the formula proposed by Husz[6]:

$$\text{Recov. Sug. \%} = \text{P.} - 0.049\text{F.}\ 1.6635 - \frac{80.7292}{24.26 + \text{Pu.}} \quad (1)$$

All sugarcane taken from each plot were weighed in order to evaluate the yield in t/ha and to calculate the yield of recoverable sugar (recov. sug. t/ha).

$$\text{Recov. Sug. t/ha} = \text{Cane t/ha} \times \frac{\text{Recov. Sug. \%}}{100} \quad (2)$$

TABLE 1. Some physical and chemical analysis of the representative soil sample

Layer depth cm	Saturation water %	pH paste	ECe mmhos/cm	Mechanical analysis Dimension of fractions in mm		
				2.000–0.50	0.50–0.002	0.002
0 – 30	48.9	7.9	4.46	26	37	37
30 – 60	50.3	7.9	4.16	35	32	33
60 – 90	51.0	8.0	3.71	43	25	32

Layer depth cm	Organic matter %	Total nitrogen %	Ratio C/N	Available nutrients			
				N* kg/ha	P** ppm	K*** mg/100 g	$CaCO_3$ %
0 – 30	2.09	0.132	10.8	68	9.5	63.5	6.5
30 – 60	2.14	0.111	13.2	54	5.4	66.5	6.8
60 – 90	1.76	0.097	12.4	50	6.7	52.7	7.3

Layer depth cm	Water-soluble ions (saturation extract) in mg/100 g of soil						
	Ca^{2+}	Mg^{2+}	K^+	Na^+	SO_4^{2-}	$C1_3^-$	HCO_3^-
0 – 30	0.496	0.299	0.051	1.796	1.985	0.489	0.159
30 – 60	0.430	0.217	0.058	1.796	1.744	0.553	0.163
60 – 90	0.316	0.173	0.042	1.554	1.710	0.382	0.140

* *Estimated*
** *Olsen method*
*** *Ammonium acetate method*

TABLE 2. F. values and coefficient of variation for the cane yield, recoverable sugar yield, and recoverable sugar %

Age	Analysis of variance					
	Cane (t/ha)		Recov. sugar (t/ha)		% recoverable sugar	
	F	C.V	F.	C.V.	F	C.V.
12.3	0.41	18.7	0.73	19.2	0.22	10.0
15.5	0.61	11.3	0.45	10.4	0.69	6.2
20.0	0.96	22.2	0.82	24.5	0.23	7.8
23.3	2.50	23.4	2.93	23.3	1.90	5.6
26.5	1.15	23.1	1.19	28.4	0.82	9.1

RESULTS AND DISCUSSION

Table 2 shows the statistical values that were obtained after the analysis of variance. These values were obtained without considering the control treatment (no N).

Considering the 5 harvesting ages which were analyzed, and use of different rates of nitrogen there was no significant statistical differences of cane yield and recoverable sugar yield or in terms of recoverable sugar %. The high values of coeficient of variation (C.V.) were due to the influence of salts.

Cane and recoverable sugar yield, in terms of the nitrogen applied

In Figs. 1A and 1B, it can be observed that both cane yield and recoverable sugar yield do not show any change with the increasing rates of N (from 180 kg /ha to 460 kg/ha). It can be seen that yields remained constant practically when cutting took place at 12.3 , 15.5 and 20.0 months. On the other hand, when cutting took place at 23.3 months there was a slight increase in yield with N. but when cutting was at 26.5 months there was a slight yield decrease in spite of the high rates of N applied. None of these differences is, however, significant.

This lack of response of sugarcane when grown on saline soil treated with high rates of N, is different from results obtained in non-saline calcarerous soil (such as the peruvian sugarcane soils), where it has been clearly proved that sugarcane response is positive when treated with rates higher than 300 kg N/ha (Standford", Evans, and Hughan and Booth in Davies and Vlitos[1]; Humbert[5]; Husz[7]; Valdivia and Tello[14]; Tello and Saldarriaga[12]; Tello and Valdivia[13]; Saldarriaga *et al.*[10]; Valdivia *et al.*[16]). However, it is important to remark that on non-saline calcareous soils that are irrigated with filter cake water mixed wih "vinaza" water (sugarcane alcohol factory waste effluent), rich in N, P and K, no response of sugarcane was obtained with nitrogeneous fertilization (Valdivia *et al*[15]; Valdi-

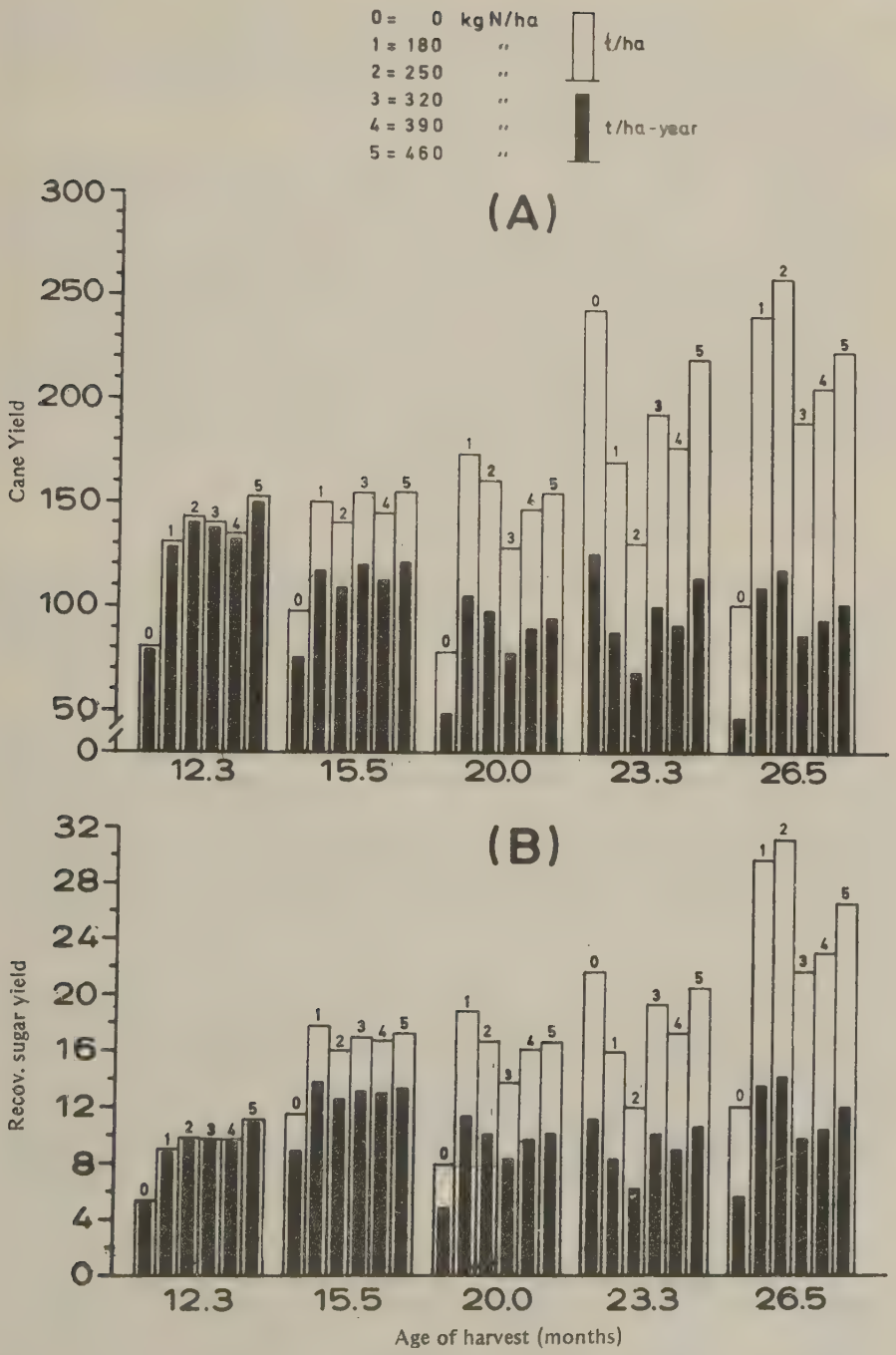

FIGURE 1. Sugarcane yield (A) and recoverable sugar yield (B) variation with harvesting age and N rates in a saline soil

via and Tello[17]). The same results were obtained on organic soil (Gonzales-Velez and Samuels[3]). Besides, on the basis of an experiment in which rates of N were as high as 450 kg/ha, Lopez and Dominguez[9] came to the conclusion that under conditions of drought no more than 168 kg N/ha should be applied.

Although in saline soils, no positive sugarcane response to high N rates was obtained, it can be seen that sugarcane without nitrogenous fertilization (control) produced an obviously lower yield than the one produced by the treatment with the lowest rate of N (180 kg/ha), except when harvesting took place at 23.3 months at which age sugarcane without nitrogen treatment had a yield 40% higher than the treatment with the lowest rate of nitrogen (180 kg/ha). This apparent contradiction, apart from showing how difficult work under conditions of salinity is, can be explained by the fact that the only control plot was located in a place where salinity was relatively low. Besides, it is necessary to say that at 12.3, 15.5, 20.0 and 26.5 months, the control treatment had respectively 38, 33, 56 and 5 % less yield than the treatment with the lowest rate of nitrogen.

Average variation of yield at different harvesting ages

Also without considering the control, it was observed that the fresh matter average yield increases with age. This result was expected because sugarcane lodges with age, new shoots develops and these stems increase the weight of harvested sugarcane (Table 3, Fig. 1).

However, the behavior of recoverable sugar yield was slightly different, it increased in about 72% from 12.3 months age to 15.5 months age (the cane yield increase under these conditions was only 6%). This remarkable increase was due to the fact that cane after 12.3 months was not yet mature but after 15.5 months sugarcane was already matured. Later on, when the canes were 20 months, although the average yield rose, the recoverable sugar yield decreased because at this age there were more suckers with low sugar concentration that decreased the quality of the whole harvested mass and, therefore, the total quantity of harvested sugar.

In Table 3, it can be seen that after 23.3 months the recoverable sugar % continued to decrease; for this reason sugar yield remained the same as the one

TABLE 3. Average yields of cane, recoverable sugar and recoverable sugar %

Age	Cane yield		Recoverable sugar yield		Recoverable sugar %
	t/ha	t/ha-year	t/ha	t/ha-year	
12.3	140.7	137.3	9.85	9.61	7.04
15.5	149.4	115.7	16.96	13.13	11.47
20.0	154.3	92.6	16.57	9.87	10.64
23.3	178.4	91.9	17.02	8.76	9.50
26.5	224.9	101.9	26.51	12.01	11.67

TABLE 4. F values (n = 100) for nitrogen, and for the nitrogen x age interaction effect

	Single effect		Interaction
	Age	Nitrogen	N x age
Cane (t/ha)	7.57**	1.05	1.53
Recov. sugar (t/ha)	13.77**	0.47	0.76
% recov. sugar	34.61**	0.19	0.80

TABLE 5. Linear correlation coefficient between the cane and recoverable sugar yields vs the salinity of the 0–60 cm layer for the different harvesting ages.

	Age (months)				
	12.3	15.5	20.0	23.3	26.5
Cane (t/ha)	– 0.31	– 0.81**	– 0.75**	– 0.83**	– 0.64**
Reco sugar (t/ha)	– 0.29	– 0.69**	– 0.81**	– 0.84**	– 0.67**

obtained when sugarcane was 15.5 months, in spite of the remarkable increase of green mass. Finally, at 26.5 months there was a remarkable yield increase because the treatments, at the last harvesting age were located in a zone with slightly less salinity than the zone where the other treatments were set up. On the other hand, a high sugar yield was obtained because the recoverable sugar average % was the highest value obtained in this experiment.

Frequently, data on the yield per year indicate the best harvesting age so that we can get as much economical profit as possible. For this reason, we have included the yields per hectare-year of both cane and sugar in Figure 1A and 1B. In Figure 1A, the highest cane per hectare – year yield was obtained when harvesting was done at 12.3 months. However, since sugarcane at this age was not yet mature, its sugar production was very low as shown in Fig. 1B. The highest recoverable sugar average yield was obtained when sugarcane was 15.5 months (Table 3), thus, indicating efficient production.

Yield variation in connection with sugarcane age and N rates

To find out the response to N x age interaction, an analysis of variance of all data was performed (n= 100).

Table 4 shows that the F value was highly significant for cane yield, the sugar yield and recoverable sugar % in connection with the simple age effect.

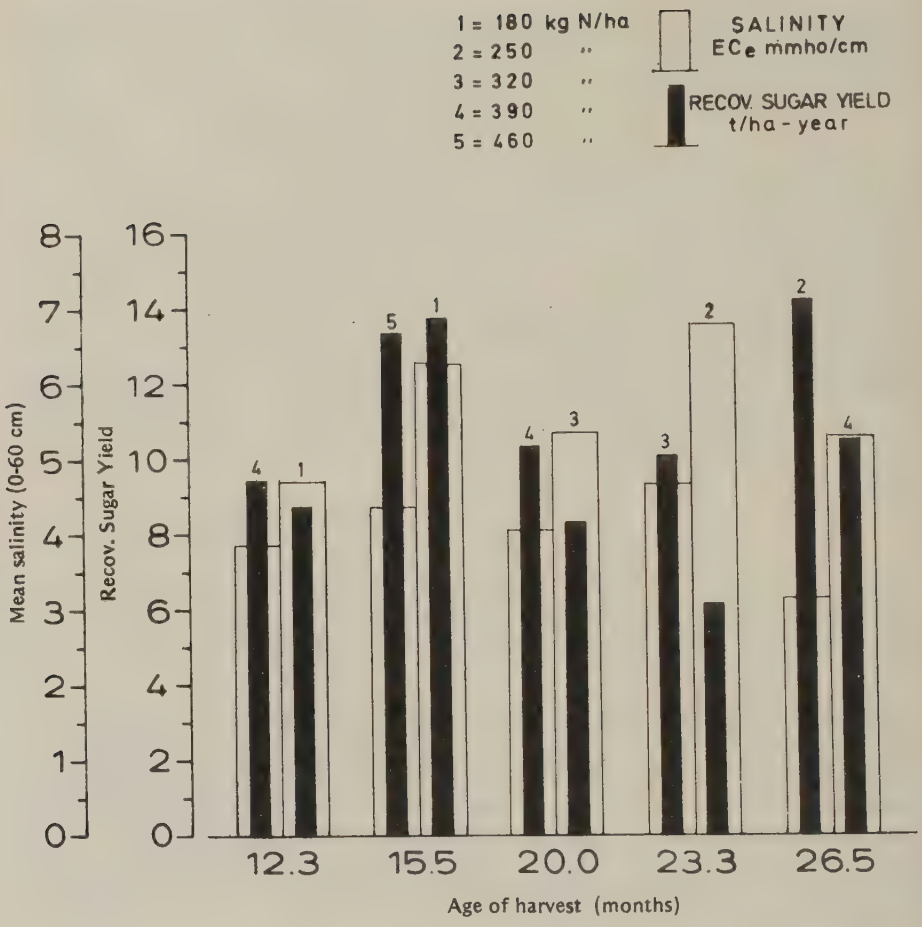

FIGURE 2. Lowest and highest average salinity (of each N treatment) with its average sugar yield, for each age of harvesting

Similarly, we can see that these characteristics are not significant in connection with the simple N effect or the effect of N x age interaction.

Influence of salinity on cane and recoverable sugar yield

Finally, a regression analysis was performed between cane and recoverable sugar yield vs. salinity of the average 0.60 cm layer, and for the 5 ages studied. In Table 5, it can be seen that at 15.5, 20.0, 23.3, and 26.5 months, there was a highly significant inverse correlation between salinity and production of both cane and recoverable sugar. Besides, it was already made clear that the lack of response to increasing N rates was due to the negative influence of salinity.

Fig. 2 shows the average yield the lowest to the highest average salinity (for each N treatment) for each harvesting age. Except at 15.5 months, there was an inverse relation between salinity and recoverable sugar yield, and this relation is higher when harvesting was done at an advanced age.

CONCLUSIONS

For slightly saline soil (from 2-8 mmhos/cm) we have arrived at the following conclusions:

- High rates of nitrogenous fertilizers have not increased cane and/or recoverable sugar yield at any of the 5 harvesting ages.
- The treatment with the lowest rate of N used (180 kg/ha) produced a higher cane and/or recoverable sugar yield than the control which means that only minimal rates of nitrogenous fertilizers are needed in terms of the saline concentration of the soil.
- On soil whose salinity is higher than 2 mmhos/cm it is necessary to use no more than 180 kg N/ha. As saline concentration increased, N application should be decreased.
- Cane yield (harvested green mass) gradually increases with harvesting age. On the other hand, recoverable sugar yield can increase and/or decrease according to harvesting age.
- Cane yield in t/ha-year is not a good indicator to determine the most adequate age for harvesting.
- Evaluation of the best harvesting age (more economical production) must be made by interpreting the data about recoverable sugar yield in t/ha-year.
- The most adequate harvesting age for cane was about 15.5 months.
- Cane and recoverable sugar yields were inversely correlated with the salinity of the soil. This negative influence did not allow us to get a response of sugarcane to fertilization by using high N rates.

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EFECTO DE LA SALINIDAD EL LA RESPUESTA DE LA CAÑA DE AZUCAR EN LA FERTILIZACION NITROGENADA.

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RESUMEN

Desde que no poseiamos informacion acerca de la respuesta de la caña de azúcar a la fertilizacion nitrogenada cuando el suelo tenia alta salinidad, fue diseñado un experimento factorial. En el experimento fueron usadas cantidades de nitrogeno (180, 250, 320, 390 y 460 kg/ha), 5 edades de cosecha (12.3, 15.5, 20.0, 23.3 y 26.5 meses), 4 replicaciones y un testigo.

La investigacion fue realizada en la Costa Norte de Peru, en el Valle de Chancay – Lambayeque, donde mas del 30% del area tiene un pobre drenaje y/o salinidad.

En esta region extremadamente arida, son predominantes los suelos aluviales, de perfil recientemente desarrollados, sin horizontes bien definidos. La salinidad del suelo varia de 2 a 8 mmhos/cm. Bajo estas condiciones se encontró que la cosecha de la caña de azucar no se incrementa aplicando altos niveles de nitrogeno. No obstante, es necesario usar minimas cantidades de fertilizantes nitrogenados y estos porcentajes estan en funcion de la concentracion salina del suelo. Ademas fúe encontrado que la caña y la produccion de azucar estaban inversamente correlacionadas con la salinidad del suelo. Finalmente tambien fue determinado que el mejor momento o epoca para la cosecha de la caña de azucar es cuando las cañas tienen 15.5. meses de edad.

NITRATE REDUCTASE ACTIVITY (NRA) AT VEGETATIVE AND REPRODUCTIVE CONDITIONS IN *SACCHARUM* CULTIVAR CO. 285

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ABSTRACT

Regulations of flowering and induction of flowering in non-flowering clones of *Saccharum* has been found possible by the application of extra light (EL) and extra dark (ED) treatments. As to the effect of EL, ED and 'switch over' treatment from EL to ED on NRA relation to flowering NRA was found to be low at vegetative stage and as the plants reached the symptom stage. The activity reached a maximum value and thereafter showing a decline with progress in flower development. Examination of germplasm collection for NRA in clones of *Saccharum* species known to differ in their flowering behaviour was suggested.

INTRODUCTION

It has been observed that plants subjected to ED treatments tend to flower much earlier as compared to normal day (ND) plants while the plants under EL remain vegetative. Biochemical studies on activities and relation to oxidizing and reducing enzymes during the vegetative and reproductive growth phases are meager and lacking. The variation in NRA at vegetative and distinct stages of flower development in hybrid sugarcane variety Co. 285 was studied and reported in this paper. The effect of EL and 'switch over' from EL to ED in relation to flowering was also studied and reported hereunder.

MATERIALS AND METHODS

Co-285, a profuse flowering variety was used in the present study. The pot culture and photoperiod treatment were patterned after Chiranjivi Rao[1]. The plants growing under ND conditions and which had reached distinct stages of flower development viz., sign of symptom, symptom, advanced short blade and arrowed were used and the NRA was estimated in the freshly-extracted stem juice. Similarly, the plants under EL and 'switch over' from EL to ED treatments were also analyzed for NRA. The method of Eckerson[4] as modified by Hibbard[6] was adopted for the determination of NRA and given below.

Measurement of NRA

Four hundred mg of KNO_3 were taken in a conical flask and 40 mg of

glucose dissolved in 5 ml distilled water was added. A suitable aliquot of the enzyme extract (5-10 ml)/or juice (i.e. stem tissue fluid 20-25 ml) and 20 ml phosphate buffer (pH 7.3) were added and the pH of the contents was adjusted to pH 7.0 with 0.2 N NaOH using phenol red as an external indicator. After adding appreciable quantity of toluene (5-8 ml), the reaction mixture was incubated at 37°C for 17 hours. The contents of the flasks were then diluted to about 70-80 ml with distilled water, treated with 8-10 g of activated carbon of 'Darco' grade and after allowing to stand for 15 minutes, filtered using Whatman No. 1 (d. 15 cm). The clear filterate was made to up a known volume (100 ml) using suitable aliquotes, the nitrate content was estimated with naphthyl amine and sulphanilic acid reagent (Snell and Snell[8]) by measuring the color in a photoelectric colorimeter and reference to a standard graph. The NRA was expressed as mg nitrate N per 100 cc juice or 100 g fresh tissue.

RESULT AND DISCUSSION

The data on the NRA in freshly-extracted stem juice at vegetative and distinct stages of flower development are given in Table 1 and shown in Fig. 1. The size of the flower dissected was also indicated. Data revealed that the NRA was very low at the vegetative stage and as the plants reached the symptom stage, the activity reached a maximum value. With further development of the flower, the NRA level fell to a minimum at advanced short blade stage and at tip emergence, the activity showed a rising tendency. The high activity at the symptom stage suggests higher rate of nitrite reduction and utilization of the reduction products for protein synthesis. Studies on NRA, nitrate nitrogen and potential nitrate nitrogen (P_N) in sugarcane revealed significant positive association of P_N with yield of sugarcane (Parthasarathi and Ramakrishnan[7], Chiranjivi Rao and Lalitha[3]).

TABLE 1. NRA in juice extracted from stem tissue of Co. 285 at distinct stages of development under normal dry condition.

Stage of development	Flower length (cm)	Nitrate reductase activity (NRA)
		(mg Nitrate N/100 ml juice)
Vegetative	–	0.00133
Sign of symptom	0.5	0.00144
Symptom	1.0	0.00238
Advance short blade	64.0	0.00126
Arrowed	69.0	0.00146
	S.E. I	0.00020

Considerable variation (five-fold) in NRA in 47 corn inbreds was reported by Hageman *et al*[5]. It was also shown that inbred M.14, an early flowering line, showed an earlier date of increase, a more rapid rate of increase and a slower decline in NRA than most other inbred lines of maize tested (Hageman *et al*[5]). Similarly, a sharp rise in NRA in relation to flowering in a late flowering variety was also observed.

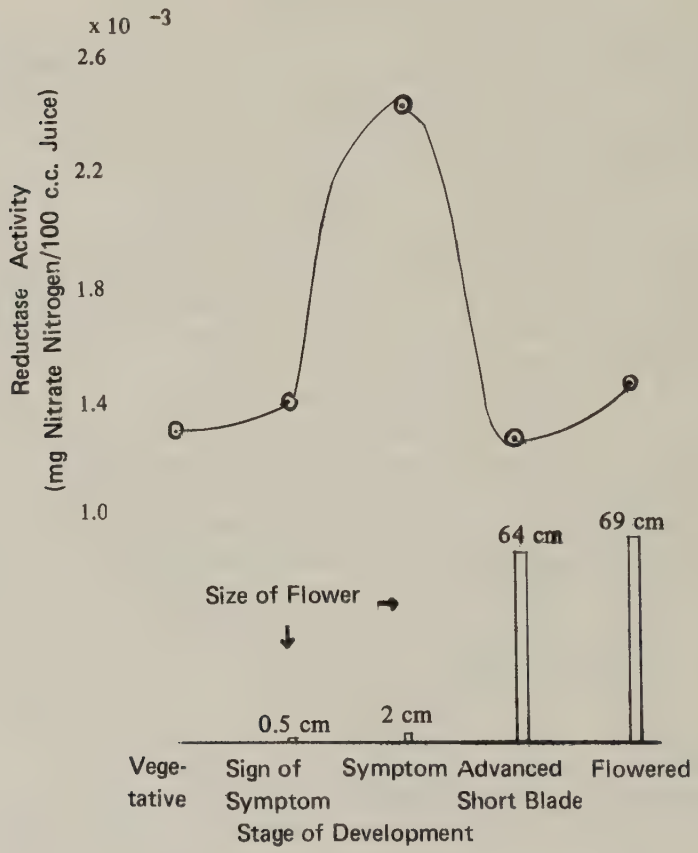

FIGURE 1. Nitrate reductase variation in stem tissue fluid (juice) of Co. 285 at distinct stages of flower development under normal day conditions. Size of inflorescence is also indicated.

The data on NRA in stem of top six leaf portion of Co. 285 plants under EL and 'switch over' from EL to ED treatments in relation to flowering are shown in Table 2. The plants under EL treatment remained vegetative and the NRA was seen to face with the progress in EL treatment. On the other hand, the two sets of plant under ED and 'switch over' from EL to ED reached symptom/advanced symptom

TABLE 2. NRA in stem (portion of top six leaves) of Co. 285 under Extra Light (EL), Extra-Dark (ED) and 'Switch Over' from Extra Light (EL) to Extra Dark (ED) treatments

Treatments	Age in days	Stage of plants*	No. of days EL/ED treatment	NRA (mg Nitrite N/100 fresh tissue)
A				
Extra light	244	Veg.	102	0.941 – 0.007
Extra dark	244	Adv. Symp.	102	1.146 – 0.010
B				
Extra light	302	Veg.	160	0.420 – 0.006
'Switch over' from EL to ED	302	Symp.	110 + 50 (EL + ED)	0.860 – 0.009
	309	Adv. Symp.	110 + 57 (EL + ED)	0.980 – 0.012

Veg. = Vegetative
Symp. = Symptom
Adv. Symp. = Advance Symptom

stage and showed higher level of NRA as compared to the corresponding EL treated plants. NRA is known to be high in leaves and low in stems. In this connection, it is interesting to note that NRA was found to be characteristically very low in all the tissues (leaf and stem) of vegetative and short blade stalks in P' 111 (Sugarcane x *Zea mays* L), a persistently non-flowering variety (Chiranjivi Rao and Vijayasaradhy[2]).

It would be worthwhile examining the NRA in relation to flowering in *Saccharum* species as considerable variation exists in the flowering behavior of *Saccharum* clones with regard to time of floral initiation, development and flower emergence. A large collection of sugarcane germplasm is available at this center and the above aspect is being examined in various clones of *Saccharum* species already catalogued for their flowering behaviour.

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ACTIVIDAD DE NITRATO "REDUCTASE" (NRA) A CONDICIONES VEGETATIVAS Y REPRODUCTIVAS EN *SACCHARUM* CULTIVAR CO. 285

K. Chiranjivi Rao y M. Vijarasaradhy

RESUMEN

La regulación e inducción de florecimiento en "clones" de *Saccharum* que no florecen fueron posibles en este Instituto por medio de aplicaciones de tratamientos extra-ligeros (EL) y de extra-oscuros (ED). Faltan estudios bioquimicos de las actividades y de la relacion de oxidacion y del reducimiento de compuestos quimicos (enzymes) con respecto al florecimiento de la caña de azucar. Se estudio la variacion en NRA en estados vegetativos asi como en otros distintos estados de desarrollos de la flor en hibridos de caña de azucar Co. 285 y estos fueron reportados en este papel. Los efectos de EL, ED y del "switch over" (tratamiento) de EL a ED en NRA en relacion al florecimiento

tambien fue examinado e incluido. Los datos revelaron que la NRA era bajo en el estado vegetativo y mientras las plantas llegaban al estado sintomatico la actividad llego al estado maximo y desde alli mostro una declinacion o caimiento en el progreso del desarrollo de la flor. La coleccion de matriz de germen (germ-plasm collection) para NRA en "clones" de especies de *Saccharum* conocidas por sus diferencias en sus modos de florecimiento.

THE EFFECT OF MANGANESE ON GROWTH, TOTAL PROTEIN AND NUCLEIC ACID IN SUGARCANE PLANT

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ABSTRACT

The physiological and biochemical effects of nitrogen metabolism in sugarcane plant raised in pure sand cultures with varying Mn levels were studied. Stunted growth accompanied by low protein content was observed in cane plants where Mn was either absent or in excess. In comparison to 0.25 ppm Mn level plant total protein was less by 54 to 55 percent and 29 to 43 percent in Mn deficient and toxic plants respectively. In immature cane plant, no definite relationship was observed between RNA content and Mn nutrition. However, 20 to 46 percent more RNA was found in normal plants than in Mn deficient and toxic plants at early stages of maturity. During early stages of growth, low DNA was accumulated in the growing regions of normal cane plant but at seventh month of age, 16 to 51 percent more DNA was found at 0.25 ppm Mn level cane plant than Mn deficient and toxic level plants.

INTRODUCTION

Nitrogen metabolism in sugarcane plant is essential for cane growth to achieve higher yield and juice quality. Among the various factors that govern nitrogen metabolism in plant, mineral nutrition occupies a significant position. Although manganese is known to be associated with the enzymes of nitrogen reduction, with free and bound amino acids, with protein synthesis and degradation and with that of nucleic acid bio-synthesis, its exact role is difficult to interpret because Mn nutritional disorder or disbalance leads to complex types of changes.

Previous studies have shown that the nutritional disorder of Mn have caused various changes in protein and nucleic acid concentrations. Vainer[15] and Valsyuk[16,17] found that Mn augments incorporation of amino acids into polypeptide chain of proteins. Mn has also been found to maintain structural entity of ribosomes (Lyletton[10]) and to stabilize tertiary and quarternary structures of protein molecule (Rickberg[12]). Yarsuenko[21], Veilmayer[19] and Valsyuk[18] reported increased protein content due to Mn application in different plant species. Ashok and Alexander[3] observed low total proteins in Mn deficient sugarcane leaves. Samuels and Alexander[13] however, could not get any trend in apical meristems of cane subjected to the variable. Enzymes necessary for the biosynthesis of nucleic acids such as RNAase, RNA polymerase and DNA polymerase showed requirement of

Mn in animal, microbial and plant cells (Salisbury and Ross[14], Valsyuk[16]). Klimovitskaya *et al*[7,8] separated different subcellular RNA and DNA and found that in peas, Mn increased the DNA content of nucleic acid chloroplasts and RNA content of the mitochondria. The influence of Mn according to these workers varies with plant in question and age. The exact relation of nucleic acids and Mn nutrition is virtually unknown in sugarcane. Alexander[1] however, indicated nutritional stress of N, P, K, Ca increased total nucleotide content in the leaves of sugarcane. In another study Alexander and Samuels[2] observed differential behavior of soluble nucleotides in cane leaves of variable Ca and Mn.

In the present investigation some of the nitrogen metabolic intermediates are studied and interpreted in terms of varying Mn nutritional status in sugarcane at different growth stages.

MATERIALS AND METHODS

Sugarcane plants (variety Co 1148) were grown with different levels of Mn for over a period of seven months in pure sand cultures. Treatments included six levels of Mn viz 0, 0.15, 0.25, 1.00, 2.00 and 100.00 ppm. All culture methodology and nutrient solution compositions have been described (Gupta and Rao[6]). Growth measurements and biochemical analysis were made at three stages of growth and at each harvest there were three replicates for every treatment. Apical meristems have been sampled in 80% ethanol and stored in cold till the time of analysis. Two grams of apical meristems were weighed and extracted thrice with water. After centrifuging out the cell debris the proteins were precipitated from supernatant by the addition of equal volumes of 10% trichloric acetic acid. The precipitate was washed thrice with 10% trichloric acetic acid, dissolved in 5 ml of 0.1N NaOH and then made up to known volume with distilled water. From these aliquots proteins were analyzed by the method of Lowry[9] and their quantities were estimated by referring to standard curve of Bovine serum albumin. Nucleic acids were extracted from 2 grams of apical meristems and were separated by the principle based on their differential acid liability (Volkine and Chan[20]). The isolation and purification methods were followed in accordance with procedures described by Neiman and Poulson[11] for higher plants with suitable modifications. The individual samples of RNA and DNA were estimated spectrophotometrically. RNA was analyzed by bial orcinol reaction for pentoses as outlined by Volkine and Chon[20]. DNA was analyzed according to method suggested by Burton[4]. Quantities of nucleic acids were determined by referring to standard curves of pure yeast RNA and calf sperm DNA supplied by Biochemical unit, New Delhi. Prior to routine analysis, the above methods were confirmed for their accuracy with phosphorus estimation (Volkine and Chon[20]) and ultraviolet absorption analysis.

RESULTS

Growth Observation

Heights of sugarcane plants grown with variable Mn levels were measured at 3rd, 5th and 7th month age of the plants (Table 1).

TABLE I Effect of manganese on the growth of sugarcane*

Treatments	Stages of growth-height expressed in cms.		
	3rd month	5th month	7th month
1	2	3	4
0.00 ppm Mn.	115	176	206
0.15 ppm Mn.	118	200	255
0.25 ppm Mn.	125	218	284
1.00 ppm Mn.	121	215	275
2.00 ppm Mn.	121	216	275
100.00 ppm Mn.	113	171	101

**Each figure represents mean of three replicates.*

Cane plants grown without Mn and with excess of Mn (treatments 1 and 6) were always lower in height than those receiving 0.25 ppm and 1.00 ppm Mn in the nutrient solutions. 0.25 ppm Mn-plants were superior to other in their heights at the three stages of growth. In the 3rd month the heights of 1.5 ppm Mn-plants were close to that of treatment 1 but with progress in age the growth retardation nullified and plant grew normally. Sugarcane growth was more affected by excess of Mn rather than by its total depletion because the heights of 100 ppm Mn-plants were always inferior to that of 0 ppm Mn-plants.

Effect of variable mn on protein concentration

Protein contents in apical-meristems of 0 ppm Mn-plants were low at all the

TABLE 2 Apical meristems total protein content of sugarcane plant raised with varying levels of manganese.*

Conc. of Mn in nutrient solutions (ppm)	Treatments protein content expressed as mg/lg dry weight of tissue		
	3-month old plants	5-month old plants	7-month old plants
1	2	3	4
0 p.	32.35	22.67	14.41
0.15	48.97	31.65	30.12
0.25	73.01	45.32	31.11
1	70.05	44.57	30.35
2	68.00	40.63	28.96
100	41.54	26.19	22.74

**Each figure represents mean of three replicates.*

stages of growth; the 0.25 ppm Mn-plants contained highest protein in their growing regions (Table 2).

As anticipated, the protein content was more in immature plants than in later stages of growth. The difference among protein contents in treatments were also pronounced at this age, and gradually decreased with progress in age. For example

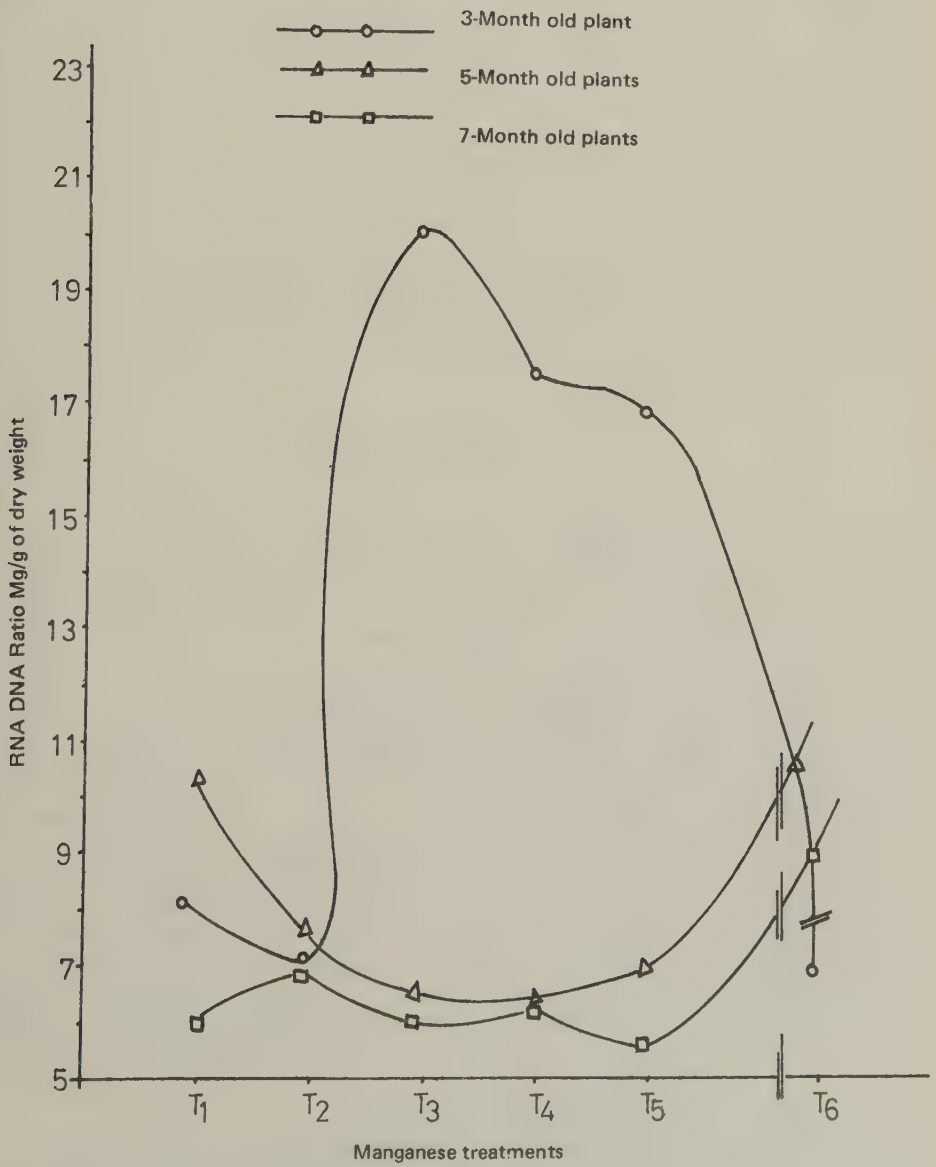

FIGURE 1. RNA/DNA ratio in apical meristems as influenced by manganese supply to sugarcane observations at 3, 5 and 7 month old plants.

TABLE 3. Effect of Manganese on nucleic acid content of sugarcane apical meristems*

Treatment Conc. of Mn in nutrient solutions (ppm)	Nucleic acids expressed as mg/gr. dry weight of tissue								
	3-month old plants			5-month old plants			7-month old plants		
	RNA	DNA	Total nucleic acids	RNA	DNA	Total nucleic acids	RNA	DNA	Total nucleic acids
0.00	163.13	20.00	183.12	145.97	14.22	160.29	67.57	11.66	79.23
0.15	142.01	20.06	162.07	156.00	21.39	177.39	75.34	11.30	86.64
0.25	228.94	10.43	239.37	165.14	25.72	190.86	84.31	14.10	98.41
1.00	141.86	8.77	150.63	166.25	26.84	193.09	84.43	13.24	97.67
2.00	186.40	11.08	197.48	135.34	24.99	160.33	62.73	12.97	75.70
100	168.27	24.34	192.61	113.58	10.26	123.84	45.35	5.79	51.14

**Each figure represents mean of three replication.*

at 3rd month protein content in treatment 3 was 55% and 43% higher than present in treatments 1 and 6, but in 7 months old plants the differences were reduced to 54 and 29% respectively. The 0.15 ppm Mn-plants initially had low protein contents but they accumulated proteins later. Throughout the growth period the differences among treatments 3, 4 and 5 were less pronounced.

Effect on variable Mn on RNA and DNA contents

RNA and DNA reacted differently with variations in Mn supply to cane plants (Table 3). No regular trend was found in 3rd month samples but in 5th and 7th month, Mn deficient and toxic plants accumulated 20% and 46% respectively less RNA than normal plants. DNA was higher in 0 ppm and 100 ppm Mn-plants at apical meristems. With progress in age however, the effect of Mn was just opposite because in 5th and 7th month samples, Mn-deficient plants accumulated 16% lower DNA than the plants grown with normal doses of Mn. Similarly meristamatic tissues of Mn-deficient plants had 51% lower DNA than that of normal (0.25 ppm Mn) plants. This result also indicated that nucleic acid accumulation was more influenced by Mn excess rather than by Mn deficiency. Total nucleic acid trends was the same as observed for RNA. With regards to RNA/DNA ratio the relationship was similar to that exhibited by DNA (Fig. 1).

DISCUSSION

Considering growth observations on one hand and protein contents on the other, it appears that cane plants totally depleted of Mn or grown in excess suffered from lowered protein synthesis or high proteolytic activity in their growing regions. The data obtained verified the observation of Ashok[3] who reported low protein content on Mn deficient cane leaves. The recovery in heights of cane plants and protein levels on 0.15 ppm Mn-plants can be attributed to age, that is, as cane growth progresses the plants accumulated more Mn and recovered from initial stress of this element. It is generally believed that sugarcane can withstand relatively high concentrations of Mn (Davis[5]). This study confirms this notion because plants which received 2.00 ppm Mn in their nutrient solutions did not either hinder the growth or protein accumulation. These indicated that physiological effect of Mn was detrimental at the very early stages of growth and carried over to the later stages. Otherwise held for nucleic acid Mn relation, as RNA and DNA did not exhibit the same trend with age. At 5th and 7th months age however, the accumulation of more nucleic acid in Mn deficient and toxic plants corroborated observations of Puerto Rican workers (Alexander and Samuels[1,2]). With the present studies it is difficult to explain contrasting behavior of DNA and RNA/DNA ratio at different stages of growth. Nonetheless, it is obvious that nature and magnitude of Mn influence on physiological process of cane varies with age.

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PARA ESTUDIAR EL EFFECTO DE MAGNESIO EN EL CRECIMIENTO, PROTEINA TOTAL Y ACIDO NUCLEICO EN LA PLANTA DE CAÑA

A. P. Gupta Y G. S. C. Rao

RESUMEN

El efecto fisiólogico y bio-quimico del metabolismo en plantas de nitrogeno en plantas de caña de azúcar crecidos en cultivos de arena pura con niveles variados de Mn, fueron estudiados aqui. Se observó un impedimento de crecimiento acompañado por un bajo contenido de proteina en plantas de caña donde habia una ausencia de Mn o donde esta se habia dado en exceso. En comparación a 0.25 ppm Mn nivel de la planta, proteina total fúe menos de 54 o 55 por ciento y 29 a 43 por ciento en deficiencia de Mn plantas toxicas, respectivamente. En plantas de caña inmadura se observo una relacion no definitiva entre el contenido de NRA y nutricion de Mn. Sin embargo, del 20 al 46 por ciento mas de RNA se encontro en plantas normales que en plantas toxicas y deficientes en Mn a principios de madurez. Durante los principios del crecimiento, un bajo de DNA se acumuló en las regiones del crecimiento de plantas normales de caña de azúcar pero a los siete meses de edad de 16 al 51 por ciento más de DNA se encontro a 0.25 ppm nivel de Mn de planta de caña que en las plantas de nivel de Mn toxicas y deficientes.

DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM (DRIS) APPLIED TO VARIOUS SUGARCANE TISSUES

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ABSTRACT

An N-P-K- fertilization trial was carried out in random blocks with three replications using variety CB41-76 on soils of Red-Yellow Podzolic-Laras variation; in the Central-South region of Brazil. This soil was previously used for pasturage.

The objectives of this trial were: the determination of sugarcane response to N-P-K fertilization, and the application of the Diagnosis and Recommendation Integrated System (DRIS) to various sugarcane tissues (leaf +3 and 8th to 10th internodes).

Results from this trial showed that there was a response to both nitrogen and phosphorus fertilization. The DRIS approach can be applied whether the tissue sample is the leaf +3 or whether it is the 8th to 10th internodes. In terms of greater ease in the collection, preparation, as well as the possiblity of early sampling, leaf +3 is preferable than the 8th to 10th internodes.

INTRODUCTION

Since the establishment of the National Alcohol Program (PRO-ALCOOL), the Brazilian sugarcane enterprises have expanded their agricultural frontiers with the objective of increasing production. This type of expansion has been taking place mainly on less fertile soils and those previously used for pasture or other crops.

Alvarez *et al*[1], while studying levels and time of N application, found that there were no differences between 75 and 150 kg N/ha, and determined that the split application of fertilizers was not necessary.

Orlando *et al*[11] noted that 4 sugarcane varieties grown of LE soil did not respond to levels and split applications of N. In this same soil type (LE) Zambello Jr. and Orlando[19] noted responses to phosphate fertilization in plant cane of variety Co740. Other soils such as CLR, PVIs, and LVal, presented no responses.

Orlando *et al*[12], while studying NPK fertilization on Ortho Dark Red Latosol

soil (LE), using variety CB41-76, noted yield responses to potassium of up to 234 kg K_2O/ha, for irrigated cane, and up to 152 kg K_2O/ha for non-irrigated cane.

Foliar analysis has been used as an index for indicating the nutritional status of the crop. Orlando and Haag[18] found a variation of 0.26% to 0.35% in P levels of leaf +3 in 16 varieties of plant cane grown on PVIs soil. Variety CB41-76 registered a P level of 0.26%.

Other sugarcane tissues used for diagnosis are the 6th to 10th internodes. Hartt[8] proposed a critical level of 0.032% P. She also noted that the quantity of phosphorus contained in the internodes was affected by N, K, Ca, Mg stage of crop development, time of harvesting the material and other climatical and edaphic factors.

Santos *et al*[15] obtained better results for the N calibration in foliar diagnosis when using the 8th to 10th internodes than with leaf +3. N levels in the case of the 8th to 10th internodes varied between 0.35% and 0.55% corresponding to the highest agricultural yields.

The Diagnosis and Recommendation Integrated System (DRIS) proposed by Beaufils[3] offers particular conditions that facilitate its application because, besides working with the interactions of the elements, it can be applied irrespective of soil types (Beaufils[2]), time of year, age of the plant (Sumner and Beaufils[17]) and time of sampling (Beaufils and Summer[4]).

Zambello Jr. and Orlando[18] tested the DRIS for the first time under Brazilian conditions using three varieties of sugarcane in Textural B "Terra Roxa" — TE soil, and presented diagrams on the nutritional balances. Later, Zambello Jr. and Orlando[20] also demonstrated the possibility of applying the DRIS irrespective of moisture conditions in irrigated and non-irrigated cane.

The objectives of this work were: the determination of sugarcane response to N-P-K fertilization on soil of Red-Yellow Podzolic-Laras variation, and the apllication of the Diagnosis and Recommendation Integrated System (DRIS to various sugarcane tissues (leaf +3 and the 8th to 10th internodes).

MATERIAL AND METHODS

The trial was carried out on soil of Red-Yellow Podzolic Laras variation (PVIs), in the Central South region of Brazil. This soil was previously used for pasturage.

Variety CB41-76 was used. This variety represents 37.4% of the cane growing area in the State of Sao Paulo (Planalsucar[13]).

The plots contained 7 rows of 10 meters in length and a spacing of 1.5m. The three middle rows were harvested for yield determination. The statistical design

used was that of random blocking with 3 replications.

The trial was installed in February of 1975, and the fertilizers used were urea, triple super-phosphate, and potassium chloride.

Table 1 shows the levels of N, P and K used. All phosphorus applications were in the furrows. Nitrogen and potassim application were made as follows: 1/3 of the doses at planting time, and the remaining at 6 months. The N and K supplementations were applied as side-dressings.

The following sugarcane tissues were collected for sampling: leaf +3 consisting of 20 central cm of the foliar blade without the midrib collected by using the technique described by Gallo *et al*[7], and the 8th, 9th, and 10th internodes, as recommended by Burr[6].

The material collected was prepared and analyzed for determination of N, P, and K as described by Sarruge and Haag[16]. Data analysis was carried out according to the Diagnosis and Recommendation Integrated System (DRIS) approach presented by Beaufils[3].

RESULTS AND DISCUSSION

Table 1 presents production results in t cane/ha and t pol/ha, where a high reaction to N and P can be seen. This can also be observed in the statistical analysis presented in Table 2. The reaction to P was that which was expected since the soil presented 20 ppm of P by the H_2SO_4 0.5 N extractor method. This level is considered insufficient by Bittencourt *et al*[5]. The reaction to N was quite high, considering that Orlando [9], recommended a rate of 60 kg/ha for sandy soils in the States of Sao Paolo. In this study, higher yields were obtained using levels of Nitrogen higher than the recommended 50 kg/ha. It should also be taken into account that this was the first time that this soil was used for cane cultivation.

The improved action of the nutrient, as demonstrated by increased yields, may be explained by the sandy texture of the soil and the fact that nitrogen was split into 2 applications which decreased leaching losses.

Although there was a 15 t cane/ha increase when levels were increased from 0 to 75 k_20/ha, as shown in Table 1., there was no notable statistical difference, as shown in Table 2. Thus, the soil revealed a level of 0.41 me K/100 ml soil which is greater than the critical level of 0.21 me k/100 g of soil suggested by Raij[14].

The regression equations were determined between yield and levels of fertilizer. The most adaptable linear equation for Nitrogen was:

$$\text{t cane/ha} = 0.2789\ (x) + 102.4 \quad F = 36.89^{**}$$
$$\text{t pol/ha} = 0.0380\ (x) + 14.75 \quad F = 33.81^{**}$$

where

x = kg N/ha.

Due to this, the economical levels of Nitrogen were impossible to be mathematically calculated. Based on the experimental results, a level of about 180 kg N/ha is recommended for N fertilization, since there is a certain tendency for yields to level off for higher N levels.

As for phosphate, the adaptation of data in Mitcherlich's equation was possible, as follows:

$$t\ cane/ha = 144.36\ \left[1\text{-}10^{-\frac{0.0207}{0.0054}(x\ +27.63)}\right]\quad F = 7.78^{**}$$
$$t\ pol/ha = 21.39\ \left[1\text{-}10^{-\frac{}{}(x+\ 106.11)}\right]\quad F = 7.01^{**}$$

where

x = kg P_2O_5/ha.

TABLE 1. Treatments applied to variety CB41-76 and their respective production (t cane/ha and t pol/ha)

Treatments (kg/ha)				
N	P_2O_5	K_2O	t cane/ha	t pol/ha
0	0	0	81	12.80
0	300	300	97	14.51
60	300	300	118	16.84
120	300	300	140	19.32
180	300	300	168	23.00
240	300	300	156	22.98
480	300	300	157	21.32
0	0	0	70	11.10
180	0	300	106	15.87
180	75	300	144	19.42
180	150	300	137	19.82
180	225	300	154	21.98
180	300	300	142	20.96
180	600	300	151	20.84
0	0	0	87	13.69
180	300	0	128	18.85
180	300	75	143	20.12
180	300	150	147	21.21
180	300	225	145	20.75
180	300	300	154	21.54
180	300	600	151	19.92

TABLE 2. Values from F test for t cane/ha t pol/ha-productions

C. Variation	G.L.	t cane/ha	t pol/ha
blocks	2	1.43	2.26
N	5	9.63**	7.56**
P	5	3.94**	3.14*
K	5	1.07	0.63
C.V.%	–	11.43	11.49
DMS (5%)	–	37	5.29

In this case, the economical levels can be presented in terms of the ratio of price/ton of cane (w) and price per kg. of the unit of P_2O_5 (t).

w/t	5	10	15	20	25
kg P_2O_5/ha	86	100	108	114	120

The application of the DRIS approach was possible for both tissues (leaf +3 and the 8th to 10th internodes), and these can be interpreted using Tables 3 and 4, and Figs. 1 and 2.

The horizontal arrows (→) indicate that the element was adequately balanced as compared to others. The slanting (↗ or ↘) arrows indicate that the element was slightly unbalanced, excessively, or insufficiently, respectively. Arrows in a vertical position such as ↑ or ↓ indicate excessive or deficient unbalanced status of the element, under study, respectively.

The interpretation of the transformed index would be that the negative values indicate insufficient levels and positive values indicate excessive levels. The closer the values of the transformed index are to zero, the more ideally balanced the samples will be.

By observing the nutritional balance of nitrogren, it can be noted that for both leaf +3 and the 6th to 10th internodes, the levelling out (→) of the deficiency occurred at a level of 180 kg N/ha. With a level of 480 kg N/ha. the 8th to 10th internodes showed an excess of N.

With respect to phosphorus, in the analysis of leaf +3 there was a leveling out of the deficiency between the levels of 75 and 150 kg P_2O_5/ha. For the 8th to the 10th internodes, the same leveling only took place between 150 and 225 kg P_2O_5/ha. If the economical ratio is around 15 (price ton cane/price kg P_2O_5), application of 108 kg P_2O_5/ha would be indicated. The DRIS approach in leaf +3 in this case would be close to the economical level. When using the DRIS approach, both the leaf +3 and the 8th to 10th internodes indicated an excess of P for the level of 600 kg P_2O_5/ha.

Although Table 2 does not reveal any statistical difference for the products between the doses of 0 and 75 kg K_2O/ha, both the analysis of leaf +3 as well as the 8th to 10th internodes showed a levelling out of the deficiency when 75 kg K_2O/ha were applied.

TABLE 3. Use of (DRIS) approach on leaf +3, plant cane of variety CB41-76, in Red Yellow Podzolic Laras variation soil.

Treatments (kg/ha)				Leaf +3*			Ratios			Balance			Transf. Indices		
N	P_2O_5	K_2O	ton cane/ha	%N	%P	%K	N/P	N / K	K/P	N	P	K	N	P	K
0	0	0	81	1.66	0.13	1.30	12.81	1.28	10.06	→	↓ ↓	→	21	– 32	32
0	300	300	97	1.71	0.16	1.42	10.90	1.20	9.09	↘	↓	→	– 41	– 12	14
60	300	300	118	1.66	0.16	1.38	10.60	1.21	8.79	↘	→	→	– 13	– 3	13
120	300	300	140	1.79	017	1.48	10.77	1.21	8.73	↓	→	→	– 12	– 6	12
180	300	300	168	1.86	0.17	1.42	11.16	1.31	8.54	→	→	→	3	– 3	3
240	300	300	156	1.91	0.18	1.43	10.80	1.34	8.08	→	→	→	0	4	– 4
480	300	300	157	2.10	0.20	1.53	10.51	1.38	7.65	→	→	↘	0	12	– 12
0	0	0	70	1.71	0.13	1.24	13.62	1.38	9.86	→	↓ ↓	→	36	– 36	24
160	0	300	106	1.73	0.11	1.32	16.32	1.32	12.41	→	↓ ↓	→	74	– 74	72
160	75	300	144	1.82	0.16	1.36	11.86	1.34	8.88	→	↓	→	13	– 13	9
160	125	300	137	1.94	0.17	1.38	11.61	1.42	8.26	→	→	↘	17	9	– 17
160	225	300	154	1.89	0.18	1.46	10.87	1.29	8.38	→	→	→	– 2	0	2
160	300	300	142	1.82	0.18	1.26	10.49	1.45	7.41	→	→	↓	9	19	– 19
160	600	300	151	1.78	0.18	1.42	10.07	1.25	8.06	→	↘	→	– 13	13	3
0	0	0	67	1.68	0.14	1.26	12.58	1.34	9.44	→	↓ ↓	→	22	– 22	18
160	300	0	126	1.90	0.18	1.32	10.54	1.44	7.38	→	→	↓	9	19	–19
160	300	5	143	1.81	0.18	1.43	10.30	1.29	8.05	↘	→	→	– 9	9	– 3
160	300	150	147	1.85	0.18	1.35	10.46	1.39	7.61	→	→	↘	0	14	– 14
160	300	225	145	1.88	0.18	1.44	10.64	1.31	8.14	→	→	→	– 4	4	0
160	300	300	154	1.84	0.17	1.44	11.03	1.28	8.62	→	→	→	– 3	– 5	5
160	300	500	151	1.86	018	1.41	10.72	1.32	8.13	→	→	→	– 3	3	– 3

* *Sampled at 8th month.*

TABLE 4. Use of (DRIS) approach on 8th to 10th internodes, plant cane of variety CB41-76, in Red-Yellow Podzolic Laras variation soil.

Treatments (kg/ha)			8th – 10th int.*				Ratios			Balance			Transf. Indices		
N	P_2O_5	K_2O	ton cane/ha	%N	%P	%K	N/P	N/K	K/P	N	P	K	N	P	K
0	0	0	81	1.39	0.04	2.10	37.03	0.72	52.68	→	↓↓	→	169	–169	147
0	300	300	97	0.84	0.08	1.76	10.89	0.47	24.73	↓	→	→	– 84	84	84
60	300	300	118	0.75	0.09	2.22	10.82	0.39	33.18	↓	→	→	– 127	45	127
120	300	300	140	0.82	0.08	1.74	10.54	0.49	21.77	↓	→	→	– 94	94	36
160	300	300	168	1.21	0.09	1.74	13.42	0.73	19.41	→	→	→	– 36	50	–50
240	300	300	156	1.43	0.09	1.95	17.64	0.74	24.50	→	→	→	10	6	–10
480	300	300	157	2.12	0.12	1.70	18.07	1.36	15.17	↑	→	↘	131	99	– 131
0	0	0	70	1.36	0.03	1.38	46.86	1.05	40.39	→	↓↓	↘	227	– 227	9
180	0	300	106	1.79	0.04	2.10	55.21	0.92	75.04	→	↓↓↓	→	333	– 333	237
180	75	300	144	1.11	0.04	1.81	31.04	0.60	52.20	→	↓↓	→	96	– 150	150
180	150	300	137	1.27	0.05	1.66	27.50	0.81	35.48	→	↘	→	87	– 87	33
180	225	300	154	1.21	0.08	1.58	16.41	0.76	21.88	→	→	→	6	26	– 26
180	300	300	142	1.08	0.08	2.02	14.16	0.55	29.27	→	→	→	– 46	12	46
180	600	300	151	1.12	0.14	1.69	8.52	0.73	12.46	→	↑	→	– 153	153	171
0	0	0	87	1.22	0.04	1.73	37.25	0.72	53.11	→	↓↓	→	171	–171	153
180	300	0	128	1.32	0.09	1.18	15.11	1.13	14.05	→	→	↓	69	123	– 123
180	300	75	143	1.01	0.09	1.48	13.11	0.63	17.12	→	→	→	62	62	– 60
180	300	150	147	1.16	0.08	1.49	15.30	0.83	19.17	→	→	→	9	51	– 51
180	300	225	145	1.14	0.11	1.71	12.11	0.82	18.27	→	→	→	– 36	63	– 63
180	300	300	154	1.22	0.09	2.07	14.84	0.61	25.67	→	→	→	– 23	23	21
180	300	600	151	1.57	0.09	2.97	18.20	0.46	39.26	→	→	↑	– 72	– 80	80

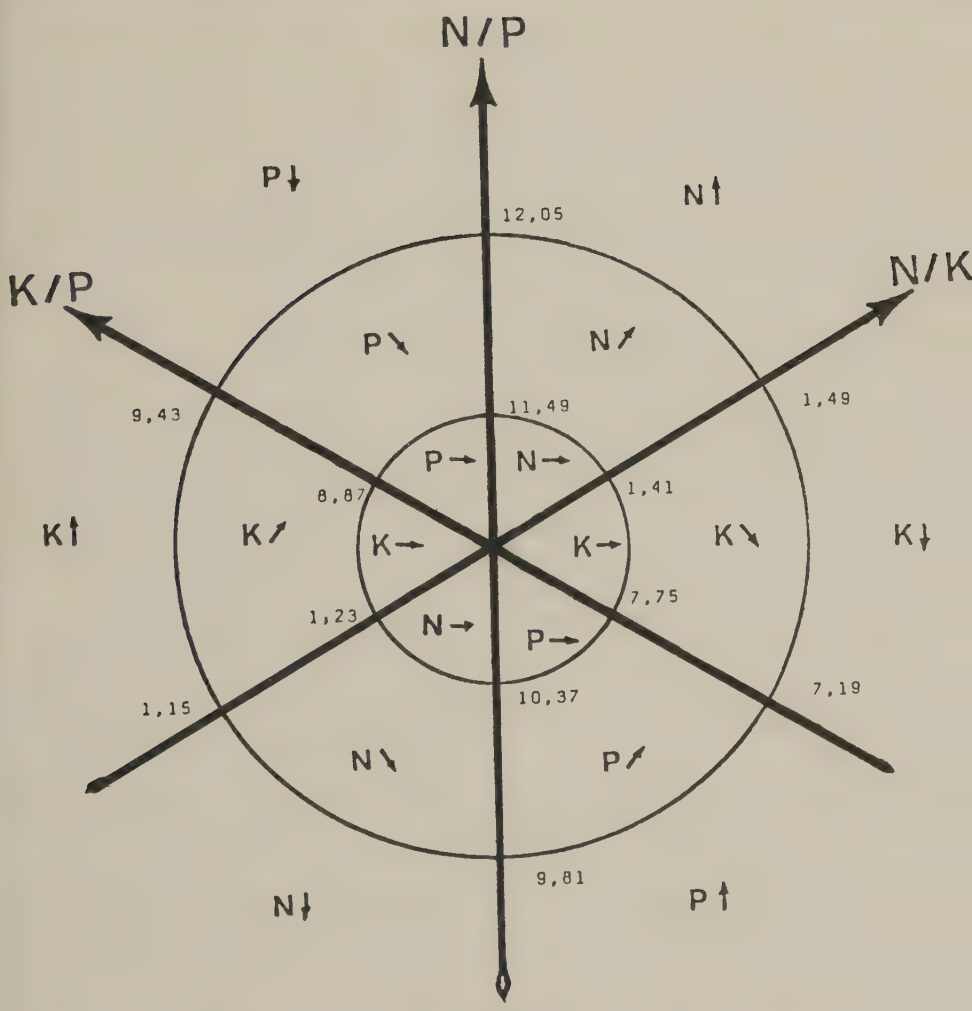

FIGURE 1. Diagram used for assessing the relative balance between N, P, K in leaf +3 in plant cane of the variety CB41-76.

Since there were no significant differences observed between the two tissues studied, leaf +3 should be selected in studies on foliar diagnosis utilizing the DRIS approach, due to greater ease in sampling and material preparation, as compared to the 8th to 10th internodes.

Also, since there was no influence of sampling time on the DRIS (Sumner and Beaufils[17]), leaf +3 presents an extra advantage over the 6th to 10th internodes in view of the possibility of its early sampling, which permits earlier correction of nutritional deficiencies.

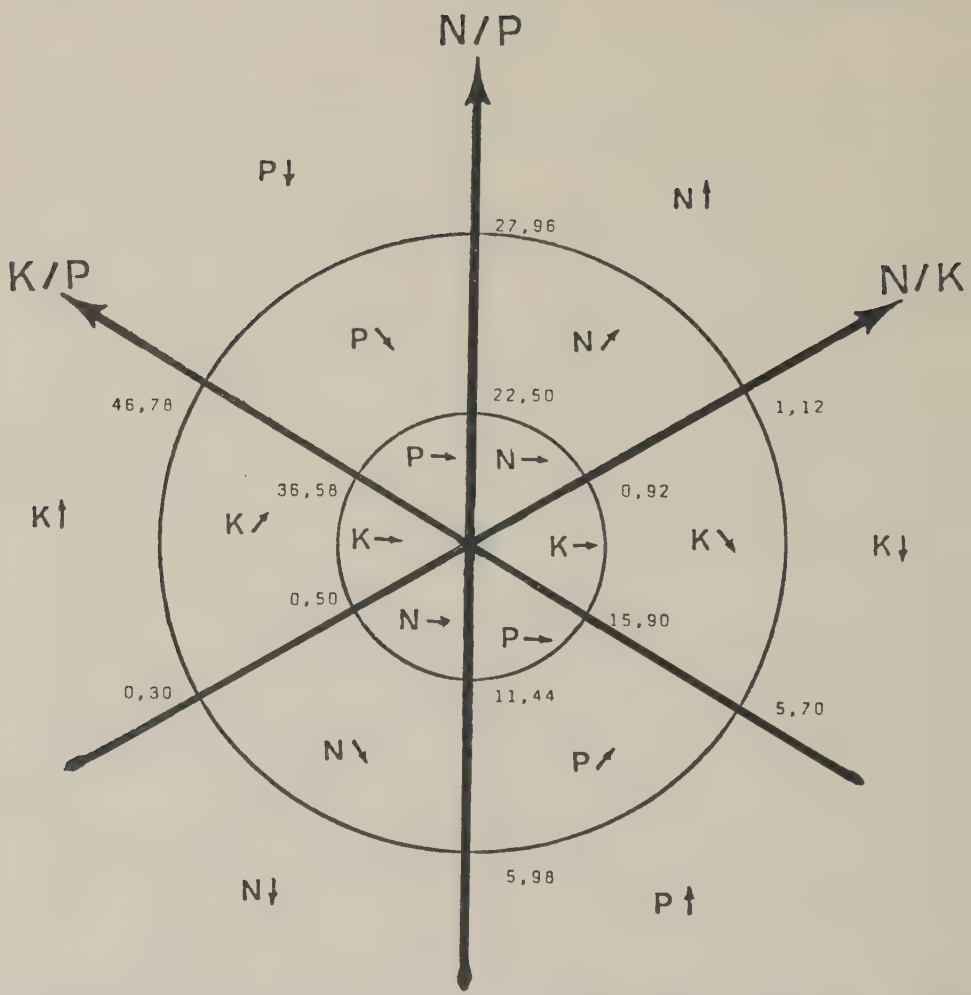

FIGURE 2. Diagram used for assessing the relative balance between N, P, K in the 8th to 10th internodes in plant cane of the variety CB41-76.

CONCLUSIONS

The following conclusions may be drawn from the results of the study:

a. There was a response to nitrogen and phosphorus fertilizers;
b. The Diagnosis and Recommendation Integrated System (DRIS) approach can be applied whether the tissue being sampled is the leaf +3 or the 8th to 10th internodes;
c. Leaf +3 should be preferred than the 8th to 10th internodes.

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SISTEMA INTEGRADO DE RECOMENDACION Y DIAGNOSIS (DRIS) APLICADO A VARIOS TEJIDOS DE LA CANA DE AZUCAR

Ermor Zambello Jr. y Jose Orlando Fo.

RESUMEN

Se llevaron a cabo ensayos de fertilizacion N-P-K en bloques al azar con tres repeticiones, usando la variedad CB 41-76 en suelos Podzolicos Rojo-Amarillos - variacion Laras, en la Región Centro-Sur del Brasil. Estos suelos habian sido usados previamento con pasturas.

Los objectivos de estos ensayos fueron: la determinacion de la respuesta de la caña de azúcar a la fertilización N-P-K; la aplicación del DRIS (Sistema Integrado de Recomendación y Diagnosis) a various tejidos de la caña de azúcar (hoja +3 y entrenudos 8° al 10°).

Los resultados de estos ensayos demuestran de que hubo respuesta tanto a la fertilización fosfatada como nitrogenada. Basado en el cociente (precio por tn. de caña/Kg. de P_2O_5), el nivel economico del fertlizante varió entre 86 a 120 Kg. de P_2O_5.

El sistema propuesto DRIS puede ser aplicado tanto a las muestras de tejidos de hojas de +3 o bien si son los entrenudos 8^o al 10^o.

Hubo cierta similitud entre los niveles economicos recomendados y la determinacion de deficiencia del fósforo cuando se usó en hoja + 3 la proposición DRIS.

SITES OF SUGARCANE CALLUS FORMATION IN YOUNG LEAF AND STEM TIP EXPLANTS

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ABSTRACT

Sites of callus origin have been histologically traced in the 40-day-old sugarcane cv. F168's young leaf and stem lip explants cultured on a modified Murashige and Skoog medium containing 3 mg/1 2,4-D. Panoramically, calli are formed on those regions of the explants which have cut wounds and are exposed to the medium. Microscopically, callus cells arose from the cambium-like cells, phloem parenchyma and the primary xylem in the vascular bundle of the leaf and stem tip explants. The newly formed callus cells are large ad vacuolated in appearance but some of them soon grow into a meristemoid. Pressure from the centrifugal growth of the meristemoids results in the appearance of many nodule-like structures along the periphery regions of the explants.

INTRODUCTION

A number of researchers have investigated the original site of callus formation in various explants of different plant species. Information on this subject would facilitate the culturists to know the potential of different tissues to proliferate *in vitro* and hence a more efficient working scheme can be undertaken. Gautheret[6] has given a diagram showing callus initiation from a variety of sites including cambium in a cultured carrot root, but his text presented no convincing histological sectons. White[13] has examined the callus origins in a mature spruce tree explant and concluded that callus formed first from the cambium, then from phloem parenchyma and finally from the lining of xylem resin ducts. Lai[8] has found that the rice's callus arose from the pericycle and endodermis of roots. Gupta[7] traced the hypocotyl callus of fenugreek by paraffin section method and revealed that the callus stemmed from the pericycle region. Dunstan *et al*[4] examined histologically a sorghum explant and found that cell divisions occurred internally and on the periphery of the seed scutellum. Liu and Chen[9] have made a morphogenetic study on the hormonal effects on the capability of organo genesis in sugar cane *(Saccharum* species hybrid) callus but presented no data to show the exact sites of callus initiation. The present investigation is intended to fill this gap and to provide sufficient histological evidences to verify the origin of the callus cells in the explants.

MATERIALS AND METHODS

Sugarcane cv. F168's stem tip tissue including 1st to 9th internodes (node

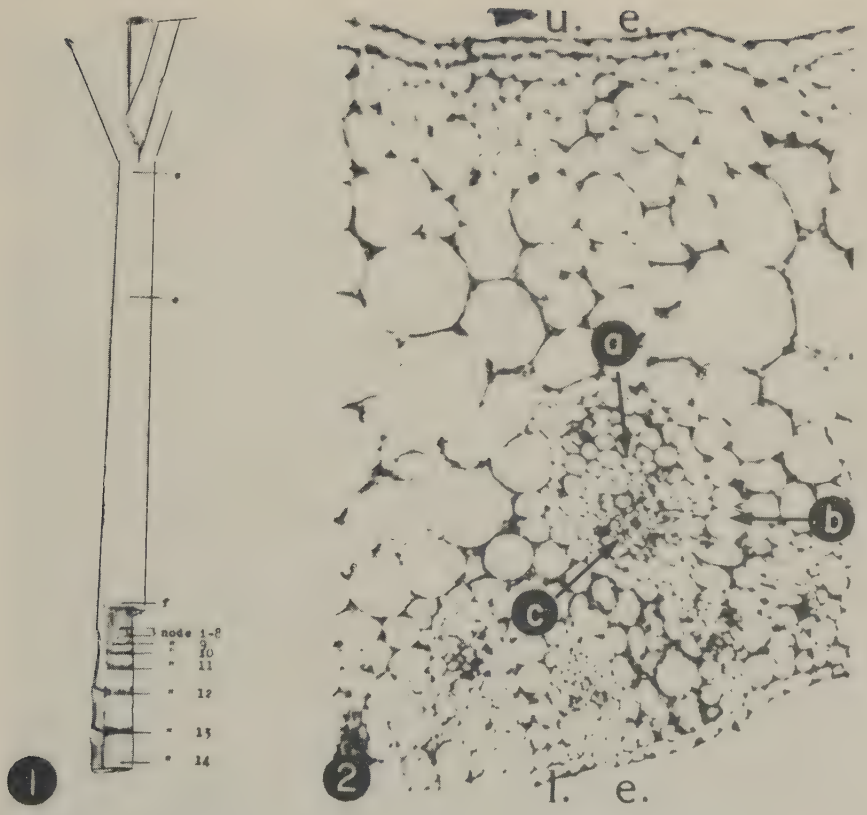

FIGURE 1. Top part of sugarcane plant with leaf sheaths cut off and stem tip split open so as to expose the growing point and the leaf portion proposed to be excised for explantation. Nodes 14, 13 and 12 have leaf sheaths already mature, d indicates the position of the termination of the leaf sheath of node 11, e of node 10 and f of node 9.

FIGURE 2. A portion of a leaf explant exhibiting the primary interior structures of a leaf blade, a = Protoxylem, b = Chlorophyll-bearing bundle sheath, e = Protophlem, u.e, = Upper epidermis, i.e. = Lower epidermis. (X 125)

designation is according to Artschwager[1]) and the 2 to 3 cm portion of the second innermost rolled young leaves right above the tip (Fig. 1) were aseptically excised and immediately inoculated on a modifed Murashige and Skoog medium[11] containing 3 mg/1 2,4-dichlorophenoxyacetic acid (2, 4-D) which is designated as non-organ-forming (NOF) medium thereafter (Liu *et al*[10]). About 5 to 7 days, callus cells started to initiate from the cut wounds of the explants. Six weeks later the explants with massive calli were cut into an appropriate size and fixed in formalin-propionic-alcohol (FPA) for 24 hrs., dehydrated with a series of tertiary butyl alcohol before being embedded in paraffin. Serial sections cut at thickness of 10 um were stained with safranin-fast green or safranin, tannic acid and orange G (Sharman[12]).

FIGURE 3. Whole view of a leaf explant with massive callus. Note the region where the callus is proliferating, at the lower epidermis (rectangular areas are enlarged in Figs. 4 and 5). (X 16).

RESULTS AND DISCUSSION

Site of young leaf callus

The young leaf when excised was not developed into clear-cut distinction between sheath and blade (Artschwager[1]). It is composed of cells in meristematic state which are similar in size (Cook[3]). Five to seven days after explanation, the

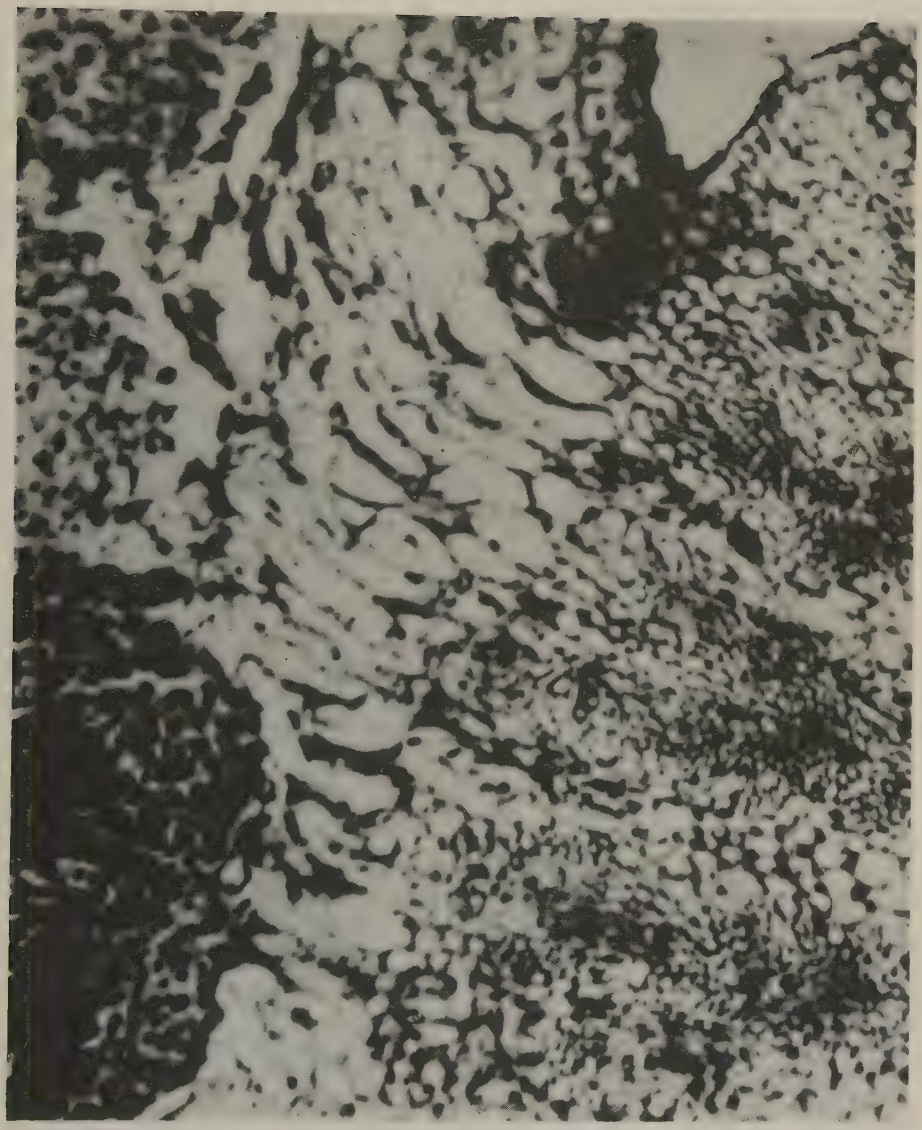

FIGURE 4. Enlargement of the upper rectangular area in Fig. 3 showing callus initiation is the result of proliferations of the cambium-like cells or phloem parenchyma of the smaller vascular bundles along the lower epidermis. (X 80).

leaf explant is gradually unrolled. This is due to the fact that certain cells along the inner epidermis (morphologically the upper surface) increase in size very rapidly, thus forcing the leaf to unfold (Fig. 2). At the time of unrolling, its interior structures such as vascular bundles, palisade cells, etc., are gradually differentiating into shape as evidenced by its turning green (Fig. 2). The greening is the result of the formation of chlorophyll in both the bundle-sheath cells and the palisade cells.

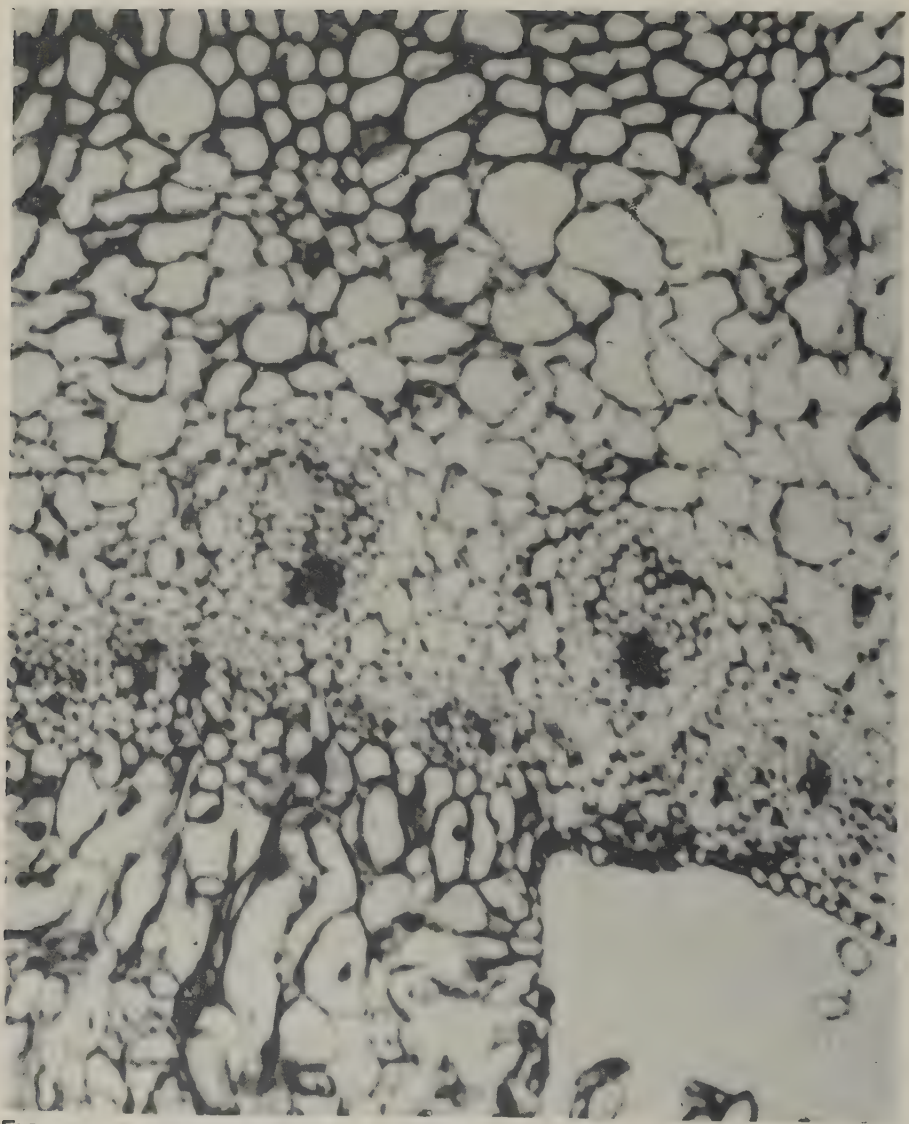

FIGURE 5. Enlarged area of the lower part of Fig. 3 showing the callus cells are mostly derived from the phloem parenchyma of the smaller vascular bundles. The callus cells are vacuolated in appearance. (X 80)

The former is surrounded by the later.

After 40 days in culture, it can be seen that numerous vascular bundles in different sizes have emerged along the lower epidermis. The small vascular bundles are situated near to the lower epidermis than the larger ones (Figs. 2 and 3).

Panoramically, callus is usually formed at the cut wounds of the explant.

FIGURE 6. Whole view of a stem-tip explant with massive callus which is growing on the periphery region (arrowed areas are enlarged in Fig. 7,8,9 and 10). X—15

Histological examination shows that callus is obviously proliferated from the cells near or in the vascular bundle because only those regions of the leaf which house the vascular bundles can produce callus (Fig. 3). This observation is of interest since Artschwager[1] has stated that in young developing leaves, cambium-like cells occur between xylem and phloem. They constitute an actively dividing tissue which some-

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ALGUNOS CONSTITUYENTES POLYPHENOLICOS DE LA PLANTA CAÑA DE AZUCAR

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RESUMEN

Un estudio detallado de los flavonoids apartados de las diferentes partes de la planta caña de azucar se ha relatado en este papel. De las cascaras de la caña de azucar, 5, 7-dimethyl apigenin, 4'-0-β-D glucopyranoside, 5-methyl apigen 4'-0-β-D galactopyranoside, peonidin-3-0-D-galactoside y leucopelargonidin se han apartado y caracterizado. De las hojas de esta planta solo un flavonoid glycoside viz. 5, 7-dimethylapigenin 4'-0-β-D glucopyranoside se ha apartado y identificado. Las flores frescas rendieron 5-methyl apigenin y 5, 7, 3', 4'-tetrahydroxy 3, 6-dimethoxy flavone. La caracterizacion de estos polyphenols ha sido hecho basado sobre los estudios quimicos y spectroscopicos.

FIGURE 9. Similar to Fig. 7 except that the enlarged area is at the lower part of the explant (c, arrowed) showing the intruding growth of a meristemoid toward the periphery region (X 80).

more localized groups of smaller and obviously meristematic cells.

Site of stem tip callus

Fig. 6 is a radial section through a 40-day-old explant with massive callus. The stem tip virtually contains the top 1-9 internodes in height of 6-10 mm. The

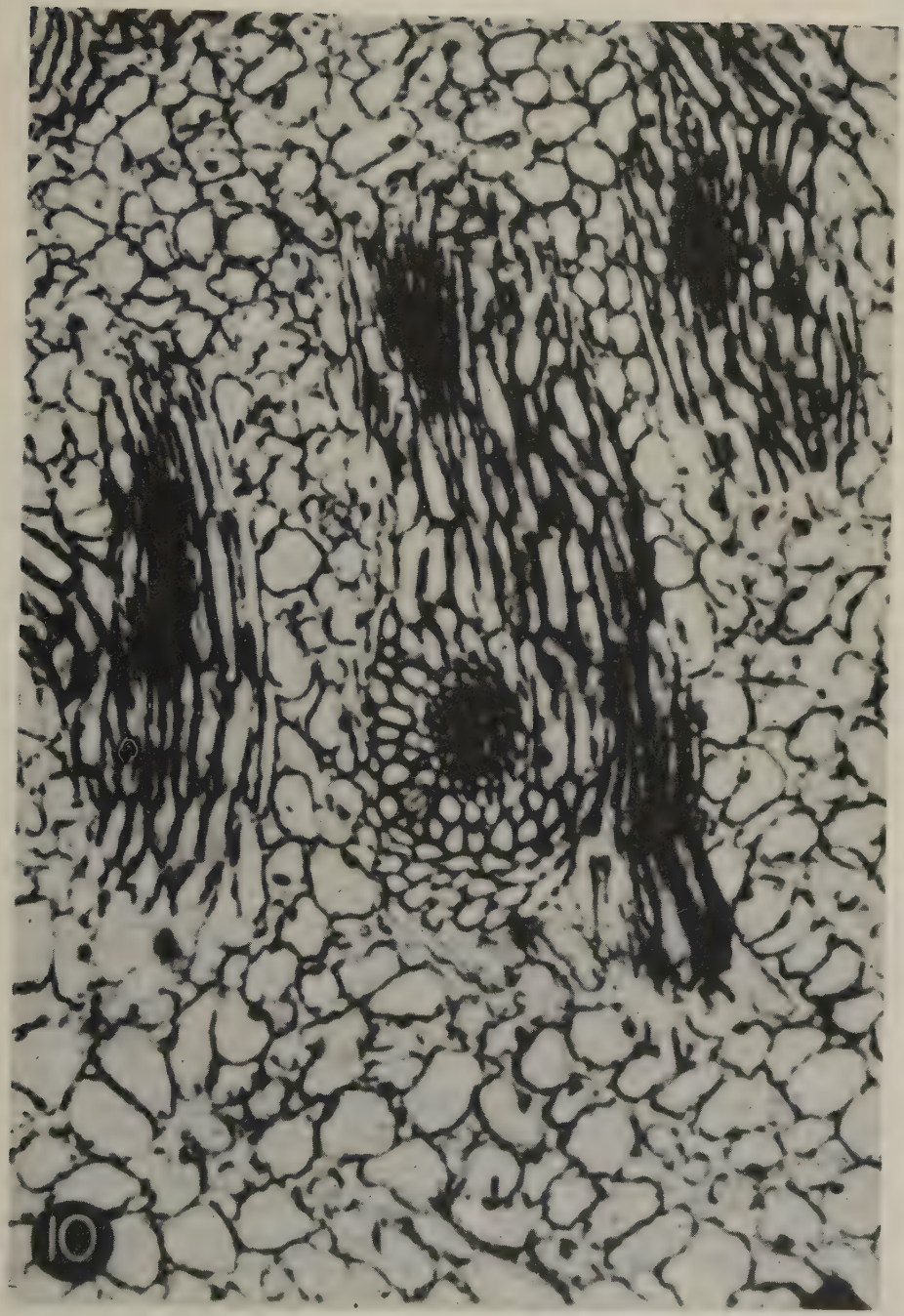

FIGURE 10. Enlarged view of a well-developed vascular bundle (d, arrowed) 6 mm away from the tip, deep embedded in the ground tissue, demonstrating no callus cell arises at all. (X 125).

apical portion is made of thin-walled meristematic cells which are in a state of active division. Some of them gradually develop into the primordia of vascular bundles and become fullpledged later (Artschwager[1]). By enlarging the callus-forming site, it is apparent that the callus is incepted form the extensive proliferations of ground vascular bundle in which the protoxylem cells play a very important role. This is based on the observation that some cells with secondary wall thickening are clearly connected with the cells of a meristemoid as seen in Fig. 7 and 9. Massive callus arising from spruce tree's cambium and young phloem region has also been reported by White[13]. The development of a meristemoid from the newly born cells is similar to the case occurring in leaf explant. The meristemoid is virtually a pro-embryoid which will develop into a shoot when transferring it onto an organ-forming medium (Liu and Chen[9]). Phloem parenchyma may also give rise to callus but this is not clearly shown in these slides. Pressure from the centrifugal growth of the meristemoids has pushed off the epidermis as shown in Fig. 8.

Those vascular bundles which are deeply embedded in the parenchymatous ground tissue of the stem tip explant will not be induced to form callus mass (Fig. 10) whereas those situated neare the periphery region can do so (Figs. 3 and 6).

From this studies it can be concluded that callus cells originate from the primary vascular bundles in both the leaf and stem tip explants. Microscpical tracing of callus origin shows that the cambium-like cells, phloem parenchyma and the primary xylem in the vascular bundles are responsible for the callus production. However, any cell which is in meristematic state can, under suitable conditions, be brought to grow and to provide callus.

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SITIOS DE FORMACION CALLOS EN HOJA JOVENES TROZOS DE TALLOS SECCIONADOS DE CAÑA DE AZUCAR.

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RESUMEN

Lugares de origen del callo han sido histologicamente reconstruidos en una planta de caña de azucar de 40 dias de edad, clon varietal F 168. Se trabajó con hojas jovenes y puntas de los tallos de la ex-planta, en el medio de cultivo Murashige y Skook modificado, conteniendo 3 mg/1 de 2,4 D.

Panoramicamente, el callo estaba formado en aquellas regiones de la ex-planta que fueron cortadas y ese corte expuesto al medio citado. Microscopicamente las celulas del callo fueron apareciendo de las celulas parecidas al cambium, floema, parenquima y del xilema primario en los vasos vasculares de los organos mencionados al principio. La nueva formacion de celulas en los callos fueron alargadas y vacuoladas en apariencia pero algunas de ellas crecieron rapidamente a meristemoides.

La presion del crecimiento centrifugo de los meristemoides, resultaron en la aparicion de muchas estructuras parecidas a nodulos, a lo largo de la region periferica de la ex-planta.

PHYSIOLOGICALLY ACTIVE PHOSPHORIC COMPOUNDS DISTRIBUTION IN SUGARCANE IN RELATION TO PHOSPHORIC NUTRITION

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ABSTRACT

The content of nucleic acids, phospholipids, macroenergy phosphorus, phytin, hexosephosphate esters and inorganic phosphorus were determined in sugarcane plants of the Cuban varitety Ja 60-5, which received three different levels of phosphorus fertilization (0, 150 and 250 kgP_2O_5/ha).

Inorganic phosphorus (Pi), with a mean value of 17.06 mg P/100 g fr wt was the fraction with the highest level. Nucleic acid was the organic fraction with the highest concentration.

The majority of phosphoric compounds with the exception of phytin and Pi were found at their highest concentration in the meristematic tissue .

Phosphoric compounds concentration are higher in leaf blades than in leaf sheaths, internodes or roots.

INTRODUCTION

Total phosphorus in plant depends upon its nutritional status, falling in the range 2-40 m moles P/kg fr wt (Nassery[8] and Ulrich[13]). Total phosphorus content may be subdivided in organic and inorganic fractions.

Although inorganic phosphorus (Pi) is more sensitive than organic phosphorus to phosphorus nutritional variations (Bieleski[2]), nutrients incorporation into organic forms is what enlarges its reaction capacity (Rubin[11]).

Almost all the phosphorus concentrated in the plant exists in the form of organic combinations, the most important are: nucleotides, nucleic acids, hexosephosphates, phospholipids (P-lipids) and phytin (Pochinok[9]).

The concurrence of different phosphorus fractions in plants related to its physiological aspects have been studied by different authors as Yakovleva[15] in

cauliflower, Byazlyvdny[3] in peas, corn and barley; and Volleidt[14] in wheat.

Hartt[5] established inorganic form of phosphorus is better related with phosphorus nutrition of plants than organic forms. Organic phosphorus was not fractioned but taken as a whole.

Lazo and Bonazzi[6] determined the distribution of phosphorus in sugarcane but in a qualitative way without discriminating among the different phosphoric compounds.

Inspite of the existing data concerning phosphoric compounds in sugarcane, it is evident that more research on them must be accomplished.

MATERIALS AND METHODS

A field experiment was conducted on a red ferralitic soil in June,1975 using plots with 8 rows and 15 m long with the Cuban sugarcane variety Ja 60-5.

Phosphoric fertilization was applied at three levels (0, 150 and 250 kg P_2O_5/ha) with a back fertilization of nitrogen and potassium of 200 kg/ha.

Agrochemical characteristics of red ferralitic soil are shown in Table 1.

TABLE 1. Agrochemical characteristics of red ferralitic soil.

Depth (cm)	ppm P*	ppm K**	pH***
0-20	8	119	7.3
10-40	7	48	7.1

* *Bray and Kurts Method 1*
** *Ammonium acetate 1N pH 7*
*** *Water 1:2.5*

Samples of a second ratoon crop were taken at the beginning (2,9 months) and at the boom stage (6,4 months) in June and October, 1977 respectively. The sample constituted by two plants taken from the middle of the plot was subdivided according to Sanchez and Clements[12], numbering leaves according to Clements and Ghotb[4], as follows:

A— Meristematic tissue (bottom 5 cm of spindle cluster)
B— Leaves +1 and +2
C— Blades +3, +4, +5 and +6 (discarding midrib)
D— Sheaths +3, +4, +5 and +6
E— Internodes +3, +4, and +6
F— Blades +7, +8, +9 and +10 (discarding midrib)
G— Sheaths +7, +8, +9 and +10

H— Internodes +7, +8 +9 and +10
I— Roots down to 40 cm depth

Pi, hexosephosphate esters, macroenergy phosphorus, phytin, P-lipids and nucleic acids were determined in fresh tissue using the Pochinok's[9] method.

All data were submitted to statistical analysis according to Lerch[7].

RESULTS AND DISCUSSIONS

Mean values for inorganic and organic phosphorus fraction concentrations are shown in Table 2.

Organic fraction is shown in the form of different compounds in the plant. Highly significant differences ($P < 0.01$) were found between Pi compounds and the different phosphorganic compounds. Phosphorus fertilization also gave significant differences ($P < 0.05$).

TABLE 2. Phosphoric compound concentration mean values at different ages and doses of fertilization (mg P/100 g fr wt)

P_2O_5 kg/ha:	0		150		250		
Age (Months):	2.9	6.4	2.9	6.4	2.9	6.4	$\bar{X}$
Compound							
Pi	15.41	14.03	18.12	18.18	21.58	15.04	17.06 a
Nucleic Acid	4.60	11.03	9.91	10.64	15.08	11.53	10.47 b
Phytin	3.97	3.59	1.18	8.38	5.79	9.05	5.33 c
P-lipids	1.21	4.07	4.01	5.68	3.54	3.45	3.66 cd
Hexosephosphate	1.15	2.61	1.41	3.12	1.61	1.97	1.98 d
Macroenergy P	1.06	2.75	1.74	1.62	3.14	0.50	1.80 d
$\bar{X}$	5.46 a		7.00 a		7.69 b		

Different letters denote significant difference at least at $P < 0.05$

Age of plant did not exert any influence upon phosphoric composition.

Table 2 shows at right, mean values ($\bar{X}$) for each phosphoric compound independent of plant section, age or dose of fertilization applied. This figures might be used as indicator values.

Mean total phosphorus content of 40.30 mg P/100 g fr wt falls within the range 2 — 40 m moles P/kg fr wt (6.2 — 124 mg P/100 g fr wt) found in plant tissues (Nassery[8] and Ulrich[13]).

Pi was the most abundant phosphorus form found (17.06 mg P/100 g fr wt).

This phosphorus form increases 24% in plants with the highest phosphorus nutrition level compared with non-fertilized plants. According to Bieleski[2], Pi is the most sensitive phosphorus fraction in tissues to phosphorus nutrition.

Pi is found at higher concentrations than any phosphorganic compound, however, taking the five organic fractions as a whole, it is more concentrated than inorganic phosphorus. Its mean value is 23.24 mg P/100 g fr wt.

This fact confirms the statement that reactive forms of mineral nutrients are organic forms (Rubin[11]).

Nucleic acids form the organic phosphorus fraction found in greater concentration, 10.47 mg P/100 g fr wt, nucleic, acid/phospholipids ratio is 3/1, which is twice the value reported as typical by Bieleski[2].

Phytin, which plays a role as P-reserve substance is found at a concentration of 5.33 mg P/100 g gr wt.

These three phosphorus compounds showed significant differences by Duncan test (see Table 2).

Phospholipids, hexosephosphate esters and macroenergy phosphorus are present at concentrations of 3.66; 1.98 and 1.80 mg P/100 g fr wt respectively, and are not significatively different by Duncan test (see Table 2).

TABLE 3. Phosphoric compound distribution in Plant (mg P/100 g fr wt)

Section	Pi	Nucleic Ac.	Phytin	P-lipids	Hexosph.	Macro-energy P
A	21.73 a	42.11 a	7.97 ab	11.30 a	6.79 a	2.13 a
B	25.02 a	7.38 bc	7.06 ac	4.28 bc	1.63 bc	2.04 a
C	35.17 b	12.26 bd	10.13 a	4.64 bc	2.80 bd	1.75 a
D	8.91 cd	3.95 c	2.39 cd	1.59 de	0.73 c	1.58 a
E	12.13 c	4.65 c	3.88 bcd	2.85 cd	0.85 c	1.70 a
F	31.58 b	14.88 d	11.18 a	5.30 b	3.25 b	1.95 a
G	8.12 cd	4.08 c	1.98 cd	1.07 e	0.57 c	1.66 a
H	4.97 d	2.07 c	2.06 cd	0.89 e	0.83 c	1.61 a
I	5.93 cd	2.83 c	1.29 d	1.05 e	0.36 c	1.83 a

Different letters denote significant difference at least at $P < 0.05$

Table 3 shows phosphorus compounds mean values in different parts of the plant without considering age or fertilization applied.

The highest concentration of phosphoric compounds, with the only exception of Pi and phytin, are localized in meristematic tissue.

Its high metabolic activity makes meristematic tissue the place of a great

amount of physiologically active compounds as nucleic acids, phospholipids, hexosephosphate esters and macroenergy phosphorus. Phytin proportionally lower concentration seems to be logical due to its role as phosphoric reservoir. Bieleski[1] and Roberts[10] have found it in small quantities in actively growing green tissues.

It is understandable that Pi, being a substrate of countless biochemical reacions, probably greater in number in a tissue like meristem, reaches a relatively small, though a high absolute value.

Invariably, all plant phosphorus forms are found in high concentrations in blade tissues. The highest were in +7, +8, +9 and +10, older than the others; followed by +3, +4, +5 and +6; and the lowest in +1 and +2, younger than the others.

All data confirm that phosphorus is present in higher concentrations in organs with highly metabolic activity in this case meristematic tissue and leaf blades, and among the last ones, the greater activity seems to be located at +7, +8, +9 and +10.

In other parts of the plant (sheaths, internodes and roots), the contents of metabolically active phosphorus compounds are smaller.

Phosphorus content in roots was low.

CONCLUSIONS

Inorganic phosphorus (Pi) is the most concentrated form of phosphorus in the plant followed by nucleic acids, while macroenergy phosphorus is the least concentrated. Their average values were 23.24, 10.47 and 1.80 mg P/100 g fr wt respectively.

The greatest physiologically active phosphorus concentrations were found in meristematic and photosynthetically active tissues. Blades +7, +8, +9 and +10 showed the greatest concentration. Roots showed the lowest phosphorus compounds concentration including Pi.

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DISTRIBUCION DE UN COMPUESTO FOSFORICO FISIOLOGICAMENTE ACTIVO EN CAÑA DE AZUCAR EN RELACION A LA NUTRICION FOSFORICA

E. Ortega and N. N. Musienko

RESUMEN

El contenido de acido nucleico, fosfolipidos, fosforo macroenergetico, fitina, ester hexosafosfato y fosforo inorganico, fue determinado

en plantas de caña de azucar de la variedad Ja 60-5 las que recibieron tres niveles diferentes de fertilizacion de fosforo (0, 150 y 250 kg/ha de P_2O_5).

El fosforo inorganico (Pi) con un valor medio de 17,06 mg de P por 100 gr de peso fresco, fue la fraccion con el mas alto nivel. El acido nucleico fue la fraccion organica con la mas alta concentracion.

La mayoria de los compuestos fosforicos se mostraron en su mas alta concentracion en el tejido meristematico con la sola excepcion de la fitina y Pi.

La concentracion de compuestos fosforicos son mas altas en las hojas que en las vainas, internodios o raices.

SOME POLYPHENOLIC CONSTITUENTS OF SUGARCANE PLANT

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ABSTRACT

A detailed study of the flavonoids isolated from different parts of sugarcane plant is reported. From the sugarcane peelings 5, 7-dimethyl apigenin 4'-O-β-D-glucopyranoside, 5-methyl apigenin 4'-O-β-D-galactopyranoside, peonidin-3-O-D-galactoside and leucopelargonidin have been isolated and characterized. From the leaves of this plant only one flavone glycoside 5, 7-dimethylapigenin 5-O-β-D-glucopyranoside has been isolated and identified. The fresh flowers yielded 5-methyl apigenin and 5,7,3,4'-tetrahydroxy 3,6-dimethoxy flavone. The characterization of these polyphenols has been done based on chemical and spectroscopic studies.

INTRODUCTION

Sugarcane is a commercially important crop. For sugar technologists the presence of colored compounds in sugarcane create difficulties during clarification of juice. The removal therefore of these colored impurities becomes necessary, particularly in view of the increasing demands for exceptionally high-quality white refined sugar. Although the presence of polyphenols in sugarcane had been reported earlier, (Zerban[24]) including tannins derived from protocatechuic acid and an anthocyanidin in the cane rind, survey of past literature indicated that sufficient knowledge about the precise chemical nature of these colored compounds is not available. It was felt that if the chemical nature of these compounds is known, it might help in introducing suitable modifications during the clarification of juice which may be of help to the sugar technologist in the production of the better quality sugar. With this in view colored constituents are isolated from peelings, leaves and flowers and their chemical structure elucidated.

MATERIALS AND METHODS

Extraction and Purification

Peelings

The dark reddish brown peelings of sugarcane were extracted with boiling ethanol. The ethanolic extract was concentrated and fractionated into ether soluble (A) and ethyl acetate soluble fractions (B). Fraction (A) gave a flavone glycoside

marked as (I) and fraction (B) gave another glycoside marked as (II). These crystallized as homogenous semicrystalline solids.

The reddish brown peelings of sugarcane when extracted with ethanolic HCl followed by concentration yielded a residue which crystallized from alcohol-HCl mixture as chocolate colored crystals and was marked as compound III.

The light colored peelings when extracted with alcohol yielded a compound marked as IV.

Leaves

Air dried leaves were extracted with boiling ethanol. The ethanolic extract after concentration was fractionated into petroleum ether(A), ether (B) and ethylacetate soluble fractions (C). Petroleum ether was found to contain chlorophyll, steroids, carotenes and some fatty acids.

Ether and ethylacetate fractions were found to contain the same compound, therefore these were combined and concentrated. Repeated crystallization from ethylacetate-petroleum ether mixture gave a chromatographically homogeneous substance, found to be identical with compound II isolated from peelings.

Flowers

The air-dried flowers were extracted with ethanol and fractionated like in the case of leaves. The light petrol fraction contained traces of carotenoids along with some waxy matter.

The ether soluble fraction gave a compound, marked as VI which was found to be identical with the aglycone of glycoside I and ethyl acetate fraction gave another compound marked as V.

DISCUSSION AND RESULTS

Compound I

The light yellow compound I isolated from peelings had m.p. 237-8° (dec) and molecular formula $C_{22}H_{22}O_{10}$. The compound gave positive Molisch[17] test and did not reduce Fehling's solution thereby suggesting its glycosidic nature. On acid hydrolysis galactose and an aglycone, m.p. 305° were obtained. This aglycone was found to be identical with the compound VI isolated from the flowers and analyzed for $C_{16}H_{12}O_5$.

Its specific color tests and λ EtOHmax nm 325 (band I) and 262 (band II) are characterized for flavones. It analyzed for one methoxyl group (found OCH_3, 9.82% Calc. for $C_{16}H_{12}O_5$ (OCH_3), 10.91%) supported by IR peaks at 1160 and 2850 cm^{-1}. The aglycone formed a diacetate found $COCH_3$, 22.58% Calc. for $C_{20}H_{16}O_7$ 23.36%) showing thereby the presence of two free hydroxyl groups (γKBr max 3500 cm^{-1}). This compound did not give any bathochromic shift (Horo

witz[11]) with $AlCl_3$ indicating thereby the absence of free-OH at position 5, or if present must be substituted. This compound further gave a bathochromic shift (Jurd[14]) at 8nm in bandII with fused sodium acetate (λ\ EtOH max-AcONa (nm), 352 (Band I), 270 (band II) clearly indicating the presence of free-OH group at 7-position of the flavone nucleus.

The aglycone on oxidation with neutral potassium permanganate gave p-hydroxy benzoic acid. This acid is obviously formed from the ring B of the flavone nucleus. Therefore, one of the hydroxyl functions must be present in para position of the ring B. Thus the position of two free phenolic hydroxyls was fixed at 7 and 4'.

The methylated compound underwent cleavage on treatment with 50% aqueous KOH producing phloroglucinol dimethyl ether and anisic acid. This finally confirmed the presence of the only methoxyl group at position 5. Thus the compound was characterized as 5-methyl apigenin.

The glycoside showed bathochromic shift (Jurd and Horowitz[14]) on addition of fused sodium acetate indicating the presence of free 7-OH group. The glycoside methyl ether on hydrolysis gave 5,7-dimethyl apigenin m.p. 295°. Therefore it could be inferred that the sugar galactose is linked to the hydroxyl at position 4' in the side phenyl. The sugar is in pyranose form which could be confirmed by periodate oxidation (Hirst and Jones[8]) of the glycoside methyl ether. Hydrolysis with emulsin (Mann and Sounders[16]) indicated that the glycosidic linkage is β in nature. Therefore, the structure assigned to the flavone glycoside (I) is 5-methyl apigenin 4'-0-β-D-galactopyranoside.

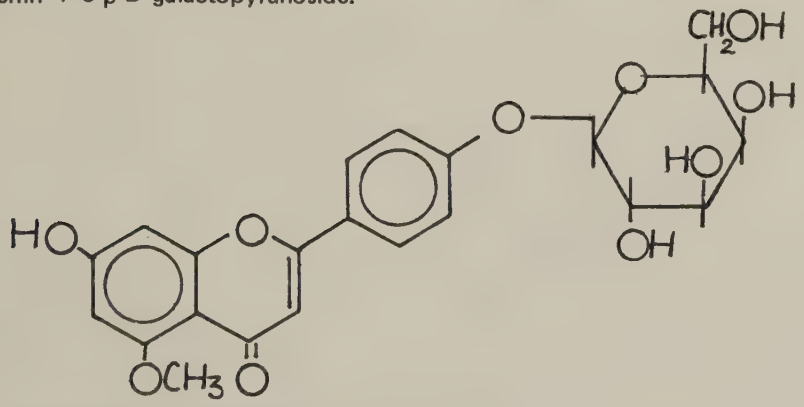

FIGURE 1. Compound I

Compound II

This crystalline compound isolated from peelings as well as leaves of sugarcane plant, had m.p. 192-93° (decomp.), analyzed for $C_{23}H_{24}O_{11}$ and gave positive Molisch[17] test suggesting the presence of carbohydrate moiety in it. However, it did not reduce Fehling's solution nor gave positive color with aniline hydrogen phthalate indicating its glycosidic nature. The compound on hydrolysis with 7% suphuric acid gave aglycone and glucose.

The cream colored aglycone, m.p. 295°, molecular formula $C_{17}H_{14}O_5$ gave positive color reactions for flavones. It showed λ\EtOH max (nm) 325 (band I) 264 (band II). It was analyzed for two methoxyl group (found: $-OCH_3$, 29.41%; calculated for $C_{17}H_{15}O_5$, 20.8%) supported by IR peaks at 1170 and 2850 Cm^{-1}. It formed monoacetate (found $-COCH_3$, 11.58%, calculated for $C_{19}H_{16}O_6$ 12.65%) indicating the presence of onehydroxyl group(λ\KBr max 3350 cm^{-1}). The compound showed no color: change with zirconium oxychloride and it gave neither any positive color: nor floure scence with oxalic acid in the presence of boric acid (Wilson[22], Neelkantam[18]), indicating the absence of free 5-OH group. This confirmed with its UV spectrum taken in presence of aluminium chloride when no bathochromic shift (Horowitz[11]) of either band was observed. This compound did not give any bathochromic shift with fused sodium acetate (Jurd[13]) indicating the absence of free 7-OH group. Further negative test (Hillis[7]) with Vanillin HCl indicated the absence of free 1,3-dihydroxy system. A large bathochromic shift[11] of 53 nm (λ \ EtOH-max $AlCl_3$ nm 378) of band I on addition of 0.002 M sodium ethoxide fixed the position for free hydroxyl group at 4'.

Alkali degradation of the aglycone gave p-hydroxy benzoic acid and dimethyl phloroglucinol, confirming the presence of two methoxyl groups at 5 and 7 positions and hydroxyl groups at 4'-position of the flavone nucleus. Therefore, the aglycone was identified as 5,7-dimethyl apigenin.

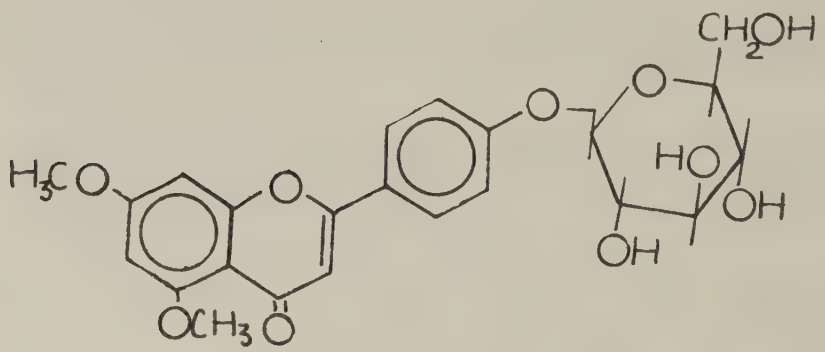

FIGURE 2. Compound II

The glycoside analyzed for $C_{23}H_{24}O_{10}$, underwent complete hydrolysis with 7% sulphuric acid easily; therefore, it could be a O-glycoside and not a C-glycoside. Since the aglycone obtained was 5,7-dimethyl apigenin, in which 5 and 7 positions are substituted by methoxyls, the only alternative left for the sugar linkage is at position 4'.

The sugar estimation indicated the presence of only one glucose moiety per mole of the glycoside. In order to determine the ring size of the glucose moiety, the glycoside was subjected to periodate oxidation (Hirst[8]). It consumed two moles

of periodate per mole of the glycoside and produced one mole of formic acid. The sugar is therefore, present in the pyranose form. Had it been in the furanose form no formic could have been produced.

The glycoside could be hydrolyzed completely with almond emulsin (Mann and Sounders[18]) thereby proving $-\beta-$ nature of the sugar linkage. On the basis of the evidences given above, the glycoside was identified as 4′ -o β-D-glucopyranoside of 5,7-dimethyl apigenin (II).

Compound III

This compound on hydrolysis with 20% aqueous HCl gave an anthocyanidin and a sugar. The anthocyanidin could be identified as peonidin by its characteristic color reactions, λ \EtOH maxHCl (nm) 542 and direct comparison with an authentic sample. The sugar was identified as D(+) galactose by its osazone formation and co-chromatography with an authentic sample. Quantitative sugar estimation indicated it to be monogalactoside. A hypsochromic shift (Jurd[15]) of 10 nm shown by the glycoside was an indication of the probable position of sugar at 3. Periodate oxidation confirmed the sugar as monogalactoside and also ring size as pyranose. Enzyme (Mann and Soundres[16]) hydrolosis established the nature of the glycosidic linkage as $-\beta-$. Thus the compound is peonidin-3-O-β-galactopyranoside (III).

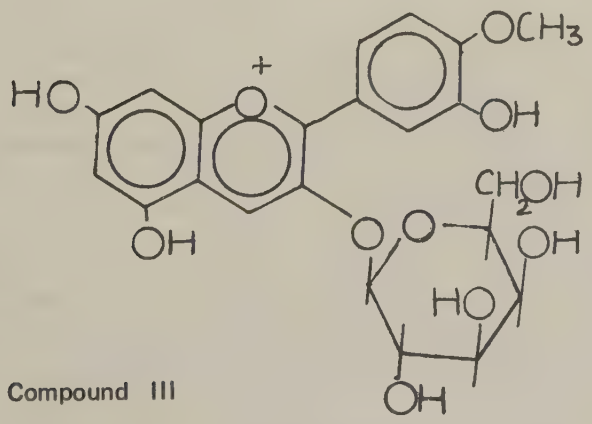

FIGURE 3 Compound III

This is a rare pigment, so far reported only in very few plant sources e.g. cranberries red (Fuleki[5]), blue black (Zapsalis[23]) and in mango fruit (John[12]).

Compound IV

This compound on heating with alcoholic hydrochloric acid gave an orange red solution which behave like naturally-occurring 3-hydroxy anthocyanidins. The original compound therefore could be a flavan-diol or leuco-anthocyanidin (Clerk-Lewis[2]). This was further characterized by its specific color reactions and spectral

data (λ \ EtOH max nm 278). Negative Molisch test indicated that it is a sugar-free entity.

The corresponding anthocyanidin could be identified as pelargonidin by color reactions, spectral studies (λ \ EtOH max HCl (nm) 540 (Harborne[9]) and paper co-chromatography with an authentic sample obtained from Salvia splendens flowers (Hayashi[6]). Therefore, the leucoanthocyanidin isolated was identified as leucopelargonidin (IV).

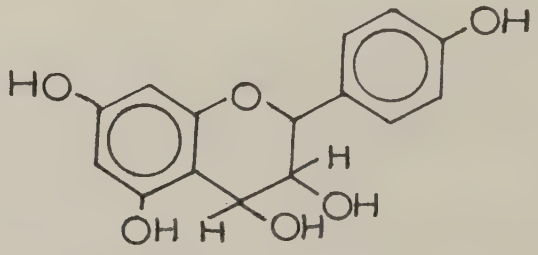

FIGURE 4. Compound IV

Compound V

Compound V, m.p. 206°, molecular formula $C_{17}H_{14}O_8$ responded to all the characteristic color reactions for flavones. Its λ \ EtOH max (nm) 357 (band I), 262 (band II) were also characteristic of flavones. It analyzed for two methoxyl groups (found $-OCH_3$, 17.48% calc. for $C_{17}H_{14}O_8$, 17.9%) supported by the IR peaks at 1180 and 2860 cm^{-1}. The compound formed a tetracetate (found $-COCH_3$, 33.0% calc. for $C_{25}H_{22}O_{12}$ 33.4%) showing thereby the presence of four hydroxyl groups (ν \ KBr max 3420 cm^{-1}).

The compound gave a strong salmon pink (Briggs[1]) color with sodium amalgam and hydrochloric acid indicating that the compound is 3-0-substituted flavone. Furthermore, the compound did not show yellow color with sirconium oxychloride in the presence of citric acid (Horhammer[10]). When the compound was refluxed with hydroiodic acid and the resulting product extracted with ether, it gave positive color reaction with zirconium oxychloride in the presence of citric acid. These reactions are characteristic of 3-hydroxy flavones, showing that the compound contained methoxyl group at position -3.

The compound exhibited bathochromic shift (Horowitz[11]) of 31 mn (λ \ EtOh-max-$AlCl_3$–HCl (nm) 388, 268) in band I clearly indicating the presence of a hydroxyl group at position-5. When treated with vanillin–HCl (Hillis[7]), the compound gave pink color which showed the presence of free 1,3-dihydroxy system in the molecule. A bathochromic shift (Jurd[14]) of 14 nm in band II (λ \ EtOH max AcONa (nm) 390, 276) was observed which also indicated the presence of a free hydroxyl group at position–7. The compound exhibited a bathochromic shift (Wilson[22]) of 16 nm (λ \ EtOH max NaOAc/H_3BO_3 (nm) 373, 274) indicating

the presence of 3',4'-dihydroxy group in the compound.

Alkali fission of the compound yielded protocatechuic acid and iretol (methoxy phloroglucinol) confirming the presence of free hydroxyl groups at 3',4' and one methoxyl group at 6 position of flavone nucleus. The methyl ether of the compound also gave veratric acid on neutral permanganate oxidation. Therefore, compound V was identified as 5,7,3',4'—tetrahydroxy—6, 3-dimethoxy flavone (quercetagetin-3, 6 dimethyl ether). Although it has been reported earlier in *Xanthium penylsyl* vanicum (Taylor[20]) and stem bark of *Cassia renigera* (Tiwari[21]) it is for the first time being reported in sugarcane flowers.

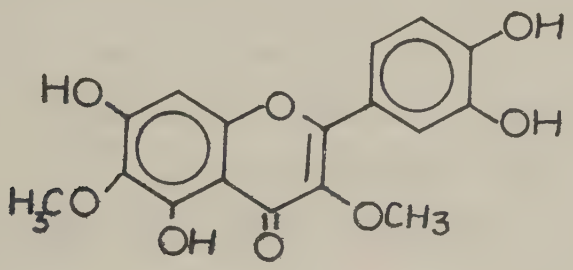

FIGURE 5. Compound V

CONCLUSION

The flavonoids isolated from different parts of the sugarcane plant appear to be biogenetically related. According to the conventional scheme acceptable for biogenesis of flavonoids, in nature, all these pigments are formed from a common precursor chalcone which arises from $C_6-C_3-C_6$ system. Cyclization, nuclear oxidation, methylation of hydroxyl groups, glycosidation and reduction of the C—3 unit involving carbonyl group and double bonds furnish explanation for the formation of flavones, flavone glycosides, anthocyanins and leucoanthocyanins. The glycosidation of these entities with glucose and its Walden product galactose is in confirmity with the presence of these sugars in abundance in sugarcane.

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ALGUNOS CONSTITUYENTES POLYPHENOLICOS DE LA PLANTA CAÑA DE AZUCAR

C.S. Mishra y K. Misra

RESUMEN

Un estudio detallado de los flavonoids apartados de las diferentes partes de la planta caña de azucar se ha relatado en este papel. De las cascaras de la caña de azucar, 5, 7-dimethyl apigenin, 4'-0-β-D glucopyranoside, 5-methyl apigen 4'-0-β-D galactopyranoside, peonidin-3-0-D-galactoside y leucopelargonidin se han apartado y caracterizado. De las hojas de esta planta solo un flavonoid glycoside viz. 5, 7-dimethylapigenin 4'-0-β-D glucopyranoside se ha apartado y identificado. Las flores frescas rendieron 5-methyl apigenin y 5, 7, 3', 4'-tetrahydroxy 3, 6-dimethoxy flavone. La caracterizacion de estos polyphenols ha sido hecho basado sobre los estudios quimicos y spectroscopicos.

EFFECTS OF PHOTOPERIOD AND TEMPERATURE ON INITIATION AND DEVELOPMENT OF FLOWERS IN SUGARCANE

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ABSTRACT

Factors influencing different phases of the flowering process were investigated. The results of the study showed that the rate of decline in daylength and temperature affected the proportions of stalks initiating tassels emerging time of anthesis and number of flowers shedding pollen. Natural sunsets, as opposed to artificial sunsets, improved flower initiation.

INTRODUCTION

Artificial induction of flowering in sugarcane has been applied successfully at Mount Edgecombe (29°S) and large numbers of crosses have been made with the flowers obtained (Brett and Harding[3]). Workers in several countries have described various aspects of the flowering process as well as some of the effects of photoperiod on flowering (Coleman[5], Julien[8], MacColl[9], Moore[10]). With the facilities available at Mount Edgecombe, it has been possible to induce flowering in many varieties, including shy-flowering varieties such as RP8 and Q82. This paper is concerned with the study done at Mount Edgecombe on the effect of photoperiod and temperature treatments on different aspects of flowering. The general objective was to increase the range of crosses which could be made.

MATERIALS AND METHODS

The procedures followed in the photoperiod house and the glasshouse have been described in detail of Brett *et al*[3]. There were five bays in the photoperiod house and three bays in the glasshouse, each with separate light controls. Temperatures were kept above 21°C. The plants were grown in sand culture in bins which were mounted on mobile trolleys.

Like other plants (Evans[6]), sugarcane requires a certain state of maturity or ripeness before the growing point responds to a flowering stimulus (Coleman[5]). At Mount Edgecombe, cane plants grown in the bins received ample water and nutrients. Two months before the start of flower initiation, applications of nitrogen are withheld until flowers initiation has taken place. Normally at the time of flower initiation, the cane is growing rapidly, all excess nitrogen has presumably been leached from the sand and the stalks have a minimum of 6 mature internodes. Cane planted for the 1978 flowering season germinated late and erratically. In

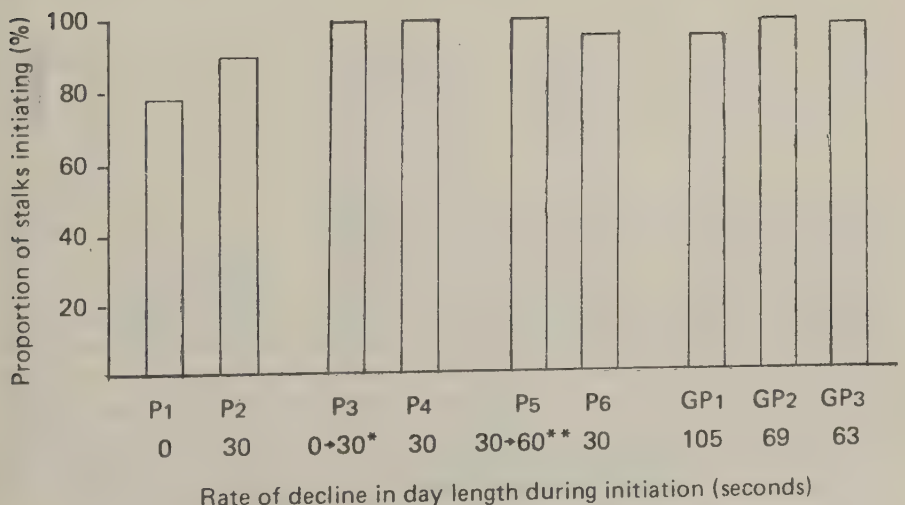
photoperiod treatments which started in March, flowering occurred up to 30 days later than expected. In treatments which started in April, flowering occurred at the expected time. The delayed flowering in the March treatments was probably due to the cane not being mature enough to respond immediately to the flowering stimulus.

Temperatures, both minimum and maximum are also important. Night temperatures above 24°C and below 21°C reduce the number of flower initials (Brett[2]). In Egypt, it was necessary to increase the humidity and reduce night temperatures for initiation to occur (Amin, Kassim, Bayaumi, Menshawi[1]). Water stress affects the initiation process. To prevent this a water table of 125 mm is maintained in the bins at Mount Edgecombe.

RESULTS

Flower initiation

The optimum daylength for the initiation of flowers has been found by most workers to be approximately 12.5h. For the sake of simplicity, the date on which the daylength was 12.5h will be regarded here as that on which initiation started.


Proportion of stalks initiating (%)
100
80
60
40
20
P1 P2 P3 P4 P5 P6 GP1 GP2 GP3
0 30 0→30* 30 30→60** 30 105 69 63
Rate of decline in day length during initiation (seconds)

P = *treatments in photoperiod house*
GP = *treatments in glasshouse*
* = *Day length kept constant for 28 days, then decreased by 30 seconds per day*
** = *Day length decreased by 30 seconds per day for 30 days, then decreased by 60 seconds per day*

FIGURE 1. Effect of rate of decrease in day length on proportion of stalks initiating flowers

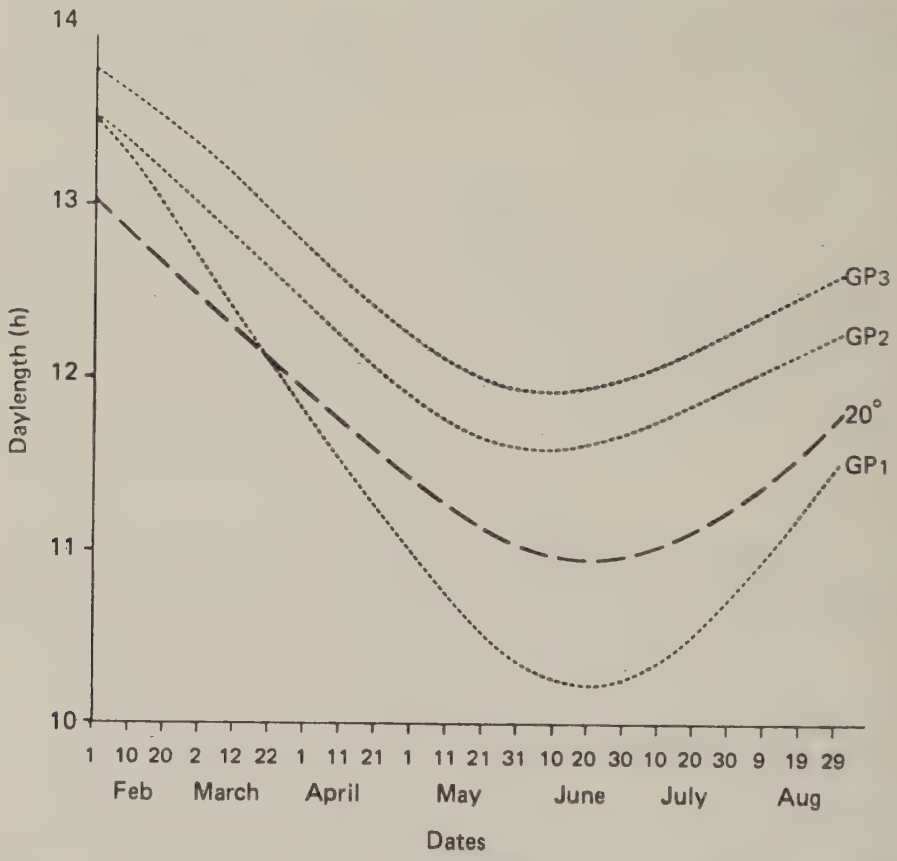


FIGURE 2. Daylengths in different treatments in the glasshouse and at 20°S latitude

Flowers in many varieties have been initiated at Mount Edgecombe with different rates of change in daylength, from a constant daylength to a decline of 100 seconds (Fig. 1). Initiation of flowering was better with a decline of 30 seconds per day (P2) than with a constant daylength (P1). Initiation was equally good in a continuous decline of 30 seconds per day, in a constant daylength for 28 days followed by a decline of 30 seconds per day (P3), and in a decline of 30 seconds per day for 30 days, followed by a decline of 60 seconds per day (P5).

In the heated glasshouse, three photoperiod treatments were implemented by having one treatment with a natural daylength (GP1) and two others in which the lights were switched on in the mornings at 05h30 (GP2) and 05h10 (GP3), respectively. With this 'artificial' dawn in treatments GP2 and GP3, the daily rates of decline, which were less than that in treatment GP1, were similar to the decline at a latitude of 20°S (Fig. 2). During 30 days after the start of initiation, the decline in daylength was 105 seconds in treatment GP1, 69 seconds in treatment GP2 and 63 seconds in treatment GP3. Flower initiation was similar in all glass-

house photoperiod treatments (Fig. 1), but fewer shy-flowering varieties initiated in treatment GP1 than in the other two treatments.

Flower initiation was better with natural sunsets than with artificial sunsets (daylength extended in the evening with lights), even when high intensity lighting was used to extend the daylength (Brett *et al* [3]). For the glasshouse experiment, initiation was also improved by leaving the cane outside until after the sun had set.

Flower initiation has taken place in a wide range of declines in daylength. Under local conditions, the most favorable decline in the photoperiod house was 30 seconds per day and 63 seconds per day in the glasshouse.

Flower Emergence

The proportion of initials producing flowers has been found to be affected by the rate of decline in daylength (Nuss and Brett[12]). For constant daylengths (P1 in Fig. 3) only 52% of the stalks flowered, compared with 87% when the decline was 30 seconds per day (2). In treatment P2, twelve varieties produced

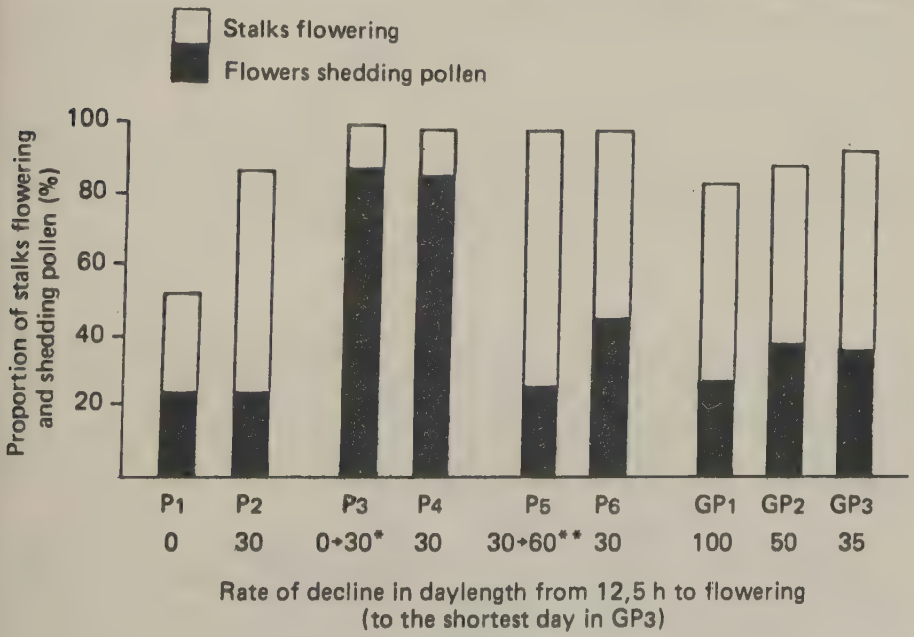


FIGURE 3. Proportion of stalks flowering and proportion of flowers shedding pollen with various declines in daylength

flowers compared with eight in treatment P1. Flower emergence was equally good in treatments P3, P4, P5 and P6, irrespective of whether the decline was consistent

(P4, P6) or was changed (P3, P5). In the glasshouse treatments, emergence was best in the treatment with the slowest decline in daylength (GP3).

In another experiment, flowers emerged in 31% of the stalks in a treatment with the same daylength as treatment GP2, but kept outside the glasshouse at ambient temperature. With the same varieties, 84% of the initials emerged in the heated glasshouse (Brett, Harding and Paxton[4]).

The proportion of stalks shedding pollen varied between photoperiod treatments. In treatment P1 only 52% of the stalks flowered, approximately half of which shed pollen. (Fig. 3). With comparable varieties with a decline of 30 seconds (P2), 87% of the stalks flowered, but only a quarter of the flowers shed pollen. When the decline was changed from 30 seconds to 60 seconds per day in treatment P5, the proportion of flowers shedding pollen was reduced to a quarter of the flowers compared to nearly half in treatment P6. The varieties used in treatments P1 and P2 were not the same as those in treatments P3, P4, P5 and P6, so differences in emergence and pollen shed between treatment in which the rate of decline in daylength was 30 seconds per day were probably due to the use of different varieties. Between 27% and 38% of the stalks flowering shed pollen in the glasshouse treatments. Flowers obtained from cane grown at ambient temperatures do not shed any pollen (Brett *et al*[4]).

Pollen differentiation occurs late in the development of the flower (MacColl[9]). At this time the flower is sensitive to changes in photoperiod and also emergence and pollen shed were good when flowers were kept at temperatures above 21°C and exposed to a gradual decline in daylength.

Time of flowering

Time of flowering has proved to be a highly repeatable character, controlled by time of initiation (Moore[10]), rate of decline in daylength (Nuss *et al*[12]) and temperature during the growth of the initial flower (Brett *et al*[4]). In artificially controlled conditions, time of initiation is independent of season and flowers have been initiated in autumn from February to May and in spring in September and October.

Pollen fertility was reduced when flowering was delayed with night light breaks (MacColl[9]) probably due to the very short phase in which pollen development took place. Delaying flower emergence increased the number of varieties shedding pollen (James[7]), presumably because the phase of pollen development was prolonged. In treatment P4 (Fig. 3) pollen shed was better than in treatment P6 probably because temperatures at the time of flowering were higher in treatment P4 than in P6.

Rate of decline in daylength

Flowering in the glasshouse with lights switched on at 05h30, was earlier than expected for no apparent reason (Brett *et al*[3]). Subsequent observations have

shown that the time of flowering was dependent on the rate of decline in daylength from initiation to flowering (Nuss *et al*[12]). At constant daylengths the number of days from initiation to anthesis (Fig. 4) was 151 compared with 119 with a 30 second decline (P1 and P2), and flowering was earlier with a 30 second decline than in a treatment of constant daylength for 28 days followed by a 30 second decline (P4 and P3). Changing the rate of decline from 30 to 60 seconds resulted in earlier flowering than with an unchanged decline of 30 seconds (P5 and P6). In the glasshouse, flowering took place earlier in treatment GP2 (50 second decline) than in treatment GP3 (35 second decline).

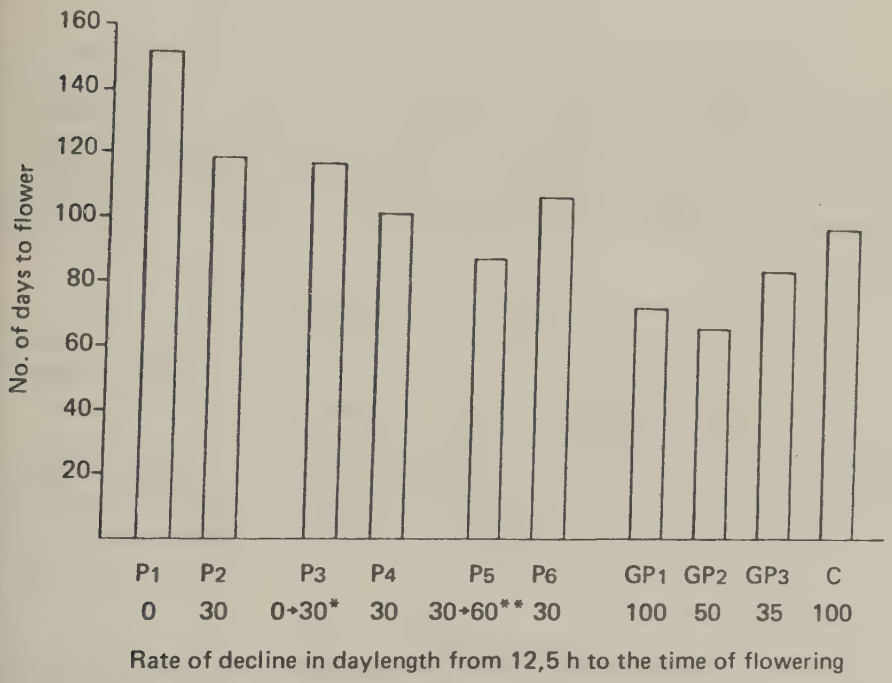

160
140
120
100
80
60
40
20
No. of days to flower
P1 P2 P3 P4 P5 P6 GP1 GP2 GP3 C
0 30 0→30* 30 30→60** 30 100 50 35 100
Rate of decline in daylength from 12,5 h to the time of flowering
P = treatments in photoperiod house
GP = treatments in glasshouse
C = Control – no heating at night
* = Decline in daylength changed 28 days and 30 days respectively, after the start of initiation

FIGURE 4. Number of days to flower with different declines in daylength.

Temperature

The plants of treatments GP1 and C were exposed to the natural rate of decline in daylength. Those in treatment GP1 were moved into a heated glasshouse (>21°C) at night and those in treatment C were kept outside at ambient temperatures. Number of days to flower was 26 more in treatment C than in treatment GP1. (Fig. 4). Temperature affects the rate of growth of a plant and presumably

therefore, the lower temperature of treatment C delayed flowering.

High temperature and low humidity at the time of pollen shed during crossing have been shown to reduce numbers of seedlings obtained per tassel (Nuss[11]). Thus, numbers of seedlings obtained were much smaller in a season in which mean daily temperature and humidity were 26,5°C and 50.3%, respectively, than in one in which the values were, respectively, 23,9°C and 56,8%.

CONCLUSIONS

The work reviewed in this paper suggests that to obtain optimum flowering (more than 90% of the stalks flowring and 30% to 40% of the flowers shedding pollen), sugarcane plants should be exposed to natural sunsets at the time of initiation, to a decline of 30 seconds per day in the photoperiod house or 35 seconds per day in the glasshouse, and to night temperatures of not less than 21°C during flower development and emergence. It has appeared, further, that time of flowering is influenced by time of initiation, rate of decline in daylength and temperature at night.

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EFFECTOS DEL FOTOPERIODO Y TEMPERATURA SOBRE LA INICIACION Y DESARROLLO DE FLORES EN CAÑA DE AZUCAR.

K. J. Nuss

RESUMEN

Fueron investigados los factores que influyen en las diferentes fases del proceso de floracion.

El ritmo de declinacion de la longitud del dia y temperatura, afectan la proporcion de tallos iniciados, panojas emergidas, hora de antesis y numeros de flores portadoras de polen. Las horas naturales de puesta del sol (opuestas a esa accion con luz artificial) mejoraron la iniciacion floral.

STUDIES ON THE EFFECT OF SOIL WATER STRESS AND LEVELS OF NITROGEN ON SPRING PLANTED SUGARCANE

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ABSTRACT

A study on the effect of soil water stress during pre-monsoon (germination and establishment stage); monsoon grand growth post-monsoon (maturity stage); and three levels of nitrogen viz 60, 120 and 180 kg N/ha on yield and quality of juice was conducted at the Indian Agricultural Research Institute, New Delhi during the two cropping seasons of 1974-75 and 1975-76. The soil of the experimental field was sandy loam in texture and medium in fertility. Sugarcane variety Co 1148, (a long duration-late maturing cultivar) was used for both seasons.

The yield of cane was adversely affected by soil water stress beyond 0.70 atm. tension at 30.0 cm at any stage. Irrigation during the dry spells during monsoon and 1 to 2 irrigation during the post-monsoon period were found to be beneficial.

Nitrogen application increased yield of millable canes but the quality of juice i.e. sucrose content in juice was adversely affected and ultimately the yield of commercial cane sugar was affected accordingly.

INTRODUCTION

Sugarcane, a twelve month duration crop, is exposed to varying evapotranspiratory (Et) demands due to distinct climatic changes in northern India. Soil water supply has, therefore, to be augmented through irrigation especially during the hot season when the Et demand is high. Studies during the recent years based on soil-moisture regimes have provided better guidance for scheduling of irrigation than the oil approaches like depth-interval-yield approach. Ray (1963) found out that maintaining a soil moisture regime of 0.70 atm. tension measured at 22 cm soil depth, throughout the crop cycle was adequate for growing a successful crop of sugarcane under Delhi conditions in sandy loam soils. The crop required 6-8 irrigations before the monsoon period and 2-3 irrigations during the post-monsoon period. Similarly, working at Padegaon on clay soils, Zende (1972) reported that a soil moisture regime of 0.04 atm. tension at 30-45 cm soil depth was conducive to

better yield of sugarcane. Rao (1972), on the other hand, clearly indicated that maintenance of uniform soil moisture regime throughout the crop cycle was not essential. Maintenance of 75% available soil moisture (ASM) in 0-30 cm soil depth during the formative stage and 25% ASM during maturity stage gave higher yields comparison with the uniform supply of irrigation water (75% ASM) throughout the crop cycle. Hence, saving a considerable amount of irrigation water, a costly input largely required by other growing crops.

However, the supply of nitrogen should also be considered besides that of water supply. Many workers have shown that higher levels of N were necessary for efficient utilization of irrigation water or vice-versa (Rege and Basu[5], Clements[1], Lakshmikantam[2] *et al.*).

The present investigation was, therefore, undertaken to assess the influence of varying soil moisture stress imposed at different growth stages in conjunction with nitrogen levels on growth, yield and quality of sugarcane with particular emphasis on water use efficiency and economy.

MATERIALS AND METHODS

The experiment was conducted at the Indian Agricultural Research Institute, New Delhi during 1974-75 and 1975-76. The soil of the experimental area was alluvial sandy loam well drained and medium in fertility (total N = 117.6 kg/ha, available P-9.1 kg/ha and available K_2O 180 kg/ha). The depth of water table varied from 2.25 m to 2.50 m. during pre-monsoon period (March-June), rose to 1.0 m depth during monsoon (July-September) and again receded to 2.0 m depth during post-monsoon (October-February) period. The available water holding capacity of the soil (FC-PWP) was 125 mm in surface 120 cm depth of soil layer.

Weather data for minimum and maximum temperature, rainfall, relative humidity, wind velocity, sunshine hours and evaporation from US WB open pan evaporimeter are presented in Table 1. The treatments consisted of eight soil-moisture regimes as given in Table 2 and three levels of nitrogen viz, 60, 120 and 180 kg/ha. Soil moisture stress was measured by installing Lark's vacuum gauge tensiometers at different depths *viz* 22.5, 30 and 37.5 cm as per treatment. The growth period was divided into three stages coinciding with the different ET demand periods.

The experimental design used was split plot in which soil-moisture stress was assigned to the main plots and nitrogen levels to the sub-plots. The treatments were replicated three times having the main plot size as 12m x 4m and sub plot being 4m x 3m.

Three budded setts of variety Co 1148 were planted 75 cm apart in furrows opened by a bullock drawn furrow opener on March 20, 1974 and March 18, 1975. Gamma BHC (1 kg ai/ha) was sprayed on the setts in furrows before covering the setts with soil in order to prevent possible damage due to white ants.

Half of the nitrogen in the form of urea was applied at planting and the other half was topdressed 60 days after planting. All of the required phosphorus (single superphosphate) and potash (muriate of potash) were applied at the rate of 80 kg P_2O_5 and K_2O/ha, respectively, at the time of planting at 5 cm deep in the furrows.

The field was plowed once using a disc plow followed by three harrowings. The land was levelled with a land plane. One day before planting the field was irrigated in the afternoon followed by two quick light discings to check evaporation losses. After planting, the field was again irrigated twice to establish the crop. Later irrigation were applied as per the treatments given in Table 2. The number of irrigation was the same for both years in stage I. (pre-monsoon period) There was no irrigation applied in stage II (monsoon-grand growth period) during 1975-76 planting as the soil did not reach the desired soil moisture stress due to regular and excessive rains. In stage III (post monsoon period), however, treatments such as no stress, stress A and stress B received the same number of irrigation for both years. The quantity of water applied during the different stages of crop growth are shown in Table 6.

The crop was harvested after 300 days in the second week of January for both years. Data on millable canes and other growth characters were recorded at harvest. Juice quality was determined as per procedure given by Spencer and Meade[6].

RESULTS AND DISCUSSION

Weather conditions

The two cropping seasons (1974-75 and 1975-76) were characteristically different in relation to mean daily temperature, total rainfall and its distribution, relative humidity, bright sunshine hours and rates of evaporation from the water surface (Table 1). The records indicate that the minimum and maximum temperature were more favorable to the second crop for early germination and late maturity. Lower temperature prevailing during the maturity period reduced evaporation losses which ultimately affected the sugar content of the cane.

The total rainfall (1200 mm) was well spread during the whole growth period while the crop received only 511 mm water through rain during the entire crop season of 1974-75. The evaporation rates also were on the lower side throughout the season baring the month of May which helped the crop in saving its energy lost through respiration. the beneficial effect of weather was reflected in increased sucrose content and yield of commercial cane sugar (Table 4).

Growth Characters

Soil-moisture regimes: Plant characters such as height of millable canes, girth at the thickest point and the number of millable canes per hectare did not show any appreciable effect due to differential soil moisture regimes during the two crop seasons, except that the plant height was significantly affected during 1975-76

TABLE 1. Mean monthly meteorological record

Month	Mean daily Temp. (C^{O})	Mean daily relative humidity (%)	total monthly rainfall (mm)	Wind velocity (km/hr)	Bright sunchine (hr)	Mean daily evaporation from USWB open Pan evaporimeter (mm)
			1974–75			
March	22.0	56	6.8	7.2	8.6	5.9
April	28.9	35	Nil	7.3	9.1	9.0
May	31.9	42	2.4	8.8	8.5	11.7
June	32.3	45	11.6	10.4	7.3	13.2
July	29.7	79	354.7	7.3	6.0	7.6
Aug.	29.0	75	111.9	6.9	6.6	7.2
Sept.	29.1	59	7.2	6.6	8.6	4.9
Oct.	24.5	54	12.3	4.1	8.2	4.2
Nov.	18.5	46	Nil	3.5	9.2	3.1
Dec.	19.1	58	4.7	5.0	7.7	2.0
Jan.	42.4	71	Nil	5.2	6.6	1.0
			1975–76			
March	19.9	51	10.1	6.8	8.6	5.2
April	27.4	35	Nil	6.5	9.5	7.9
May	32.0	35	Nil	9.3	7.8	12.4
June	31.8	59	120.1	10.5	5.7	12.9
July	29.4	75	343.3	9.0	6.5	7.4
Aug.	28.4	83	328.4	6.2	5.3	5.0
Sept.	27.1	84	340.4	5.3	5.2	4.7
Oct.	24.5	62	58.0	3.9	9.3	3.6
Nov.	17.3	57	Nil	3.9	9.3	2.6
Dec.	14.2	72	Nil	4.6	8.6	2.0
Jan.	14.2	73	Nil	4.7	7.0	1.7

(Table 1). The data reveal that subjecting the soil to a higher degree of soil mositure stress (0.7 atm tension at 37.5 cm) during pre-monsoon season i.e. establishment stage, the height of the cane significantly reduced. Similarly, no irrigation during the post-monsoon season also reduced the cane height significantly.

The setback to the crop due to the imposition of higher soil moisture stress during pre-monsoon and post-monsoon stages may be due to high atmospheric demands during the hot months in the establishment stages and high transpiration rates due to extensive foliage growth in the later stages of crop growth.

The sugarcane crop did not apparently require any extra irrigation water during monsoon period due to adequate natural precipitation, expanded root zone and the rise in water table. During the monsoon, apart from adequate rainfall, the water table rose to 1 m below the surface soil layers and thus it was within the reach of the roots and there was no response to the additional water applied during monsoon season.

Nitrogen application

Unlike the effect of soil-moisture regimes, nitrogen levels affected the plant characters significantly with increasing levels of nitrogen. Cane height increased significantly up to 120 kg N/ha during the first year while in the second year significant increase was recorded at every increment in the nitrogen dose. The girth of cane was affected only in the first year when the cane thickness showed significant increase under 180 kg N/ha. The number of canes also increased with the increase in nitrogen supply but the significant effect was only seen in the second year when the number of millable canes increased significantly with every increment in nitrogen supply (Table 2).

Yield and quality of cane

Effect of irrigation: The yield of millable canes was affected significantly by soil-moisture stress. The decrease in yield was marked when the crop remained unirrigated during the monsoon season and experienced soil moisture stress or no irrigation during the post-monsoon season. The results clearly indicate that dry spells or unirrigated situations also cause significant reduction in cane yield if the crop is exposed to such conditions during monsoon and post-monsoon periods. The present findings collaborate the results reported by Ray[4] and Zende[8].

Sucrose content and purity coefficient in cane juice remained unaffected due to different irrigation treatments imposed either during pre-monsoon, monsoon or post-monsoon seasons. Commercial cane sugar did not show any remarkable effect due to irrigation treatment during the first year but the reduction in C.C.S. was observed during the second year. The drop in cane sugar started to occur when the crop experienced soil moisture stress beyond stress 'A' in the pre-monsoon seasons and no irrigation and stress 'A' or stress 'B' in the post-monsoon seasons (Table 4). It may be concluded from the foregoing results that the yields of millable cane and commercial cane sugar show significant reduction if the crop is exposed to water stress at any stage of growth.

Nitrogen effect

Nitrogen effect: The yield of millable canes increased significantly with every increment in nitrogen dose for both years. Highest yield of cane (77.6 t/ha) was recorded under the highest dose of N (180 kg N/ha). (Table 5). The sucrose content in cane juice reduced with the increase in nitrogen rate. The reduction in sucrose content was significant only during the first year where the highest percentage (16.4) of sucrose was recorded under 60 kg N/ha while the lowest (14.5) was observed under the highest dose of nitrogen application. Similar effect was also observed in the case of purity coefficient in juice. The yield of commercial cane sugar increased with the increasing dose of nitrogen but the increase was significant only during the second year. The magnitude of increase under 120 and 180 kg N/ha over 60 kg N/ha was 20.6 and 44.7%, respectively.

TABLE 2. Effect of soil moisture regimes on growth characters of sugarcane

Soil Moisture Stress				Height of canes (cm)		Dia of canes (mm)		Number of millable canes & ha (1	
Stage I Establishment and tillering (Pre-monsoon)	Stage II Grand growth (Monsoon)	Stage III Maturation (Post-Monsoon)	Number of differential Irrigations	1974-75	1975-76	1974-75	1975-76	1974–1975	1975-76
No stress	No stress	No stress	11	162	182	31	22	77.8	107
Stress 'A'	No stress	No stress	7	150	178	33	21	87.0	100
Sterss 'B'	No stress	No stress	7	147	154	32	22	78.2	101
No stress	No Irrigation	No stress	9	159	182	34	22	77.0	96
No stress	No Irrigation	Stress 'A'	8	147	184	32	23	81.2	97
No stress	No Irrigation	Stress 'B'	8	145	172	33	22	72.3	101
No stress	No stress	No Irrigation	9	138	156	32	21	78.8	99
No stress	No Irrigation	No Irrigation	7	140	176	33	21	69.9	94
C. D. 5%				N.S.	20.0	N.S.	N.S.	N.S.	N.S.

No stress – *Irrigation applied at 0.7 atm. tension at 22.5 cm soil depth*
Stress 'A' – *Irrigation applied at 0.7 atm. tension at 30.0 cm soil depth*
Stress 'B' – *Irrigation applied at 0.7 atm. tension at 37.5 cm soil depth*
N. S. – *Not significant*

TABLE 3. Effect of levels of nitrogen on growth characters of sugarcane

Levels of nitrogen (kg N / ha)	Height of canes (cm)		Mean	Dia of canes (mm)		Mean	No. of canes / ha (103)		Mean
	1974-75	1975-76		1974-75	1975-76		1974–75	1975-76	
60	140	159	149.5	31	21	26	74.1	92.3	85.7
120	151	173	162.0	33	22	27.5	78.4	100.8	89.6
180	154	187	170.5	34	22	28.0	80.5	109.3	94.9
CD 5%	8.3	4.5	–	2.2	N.S.	–	N. S.	4.7	

TABLE 4. Effect of soil moisture stress on yield of canes, juice quality and yield of commercial cane sugar (CCS).

Soil moisture stress			Yield of millable canes (t/ha)		Mean	Sucrose Content (%)		Purity Coefficient (%)		Commercial cane sugar (t/ha)	
Stage I	Stage II	Stage III	1974-75	1975-76		1974-75	1975-76	1974-75	1975-76	1974-75	1975-76
No stress	No stress	No stress	76.4	75.3	75.9	15.7	1.63	81.9	86.0	7.9	8.3
Stress 'A'	No stress	No stress	76.4	71.1	73.7	15.2	16.4	80.0	87.7	7.6	8.0
Stress 'B'	No stress	No stress	71.9	71.8	71.8	15.1	16.3	78.7	87.0	7.9	6.8
No stress	No Irrigation	No stress	79.2	62.1	70.6	15.4	16.4	78.9	89.3	7.9	7.1
No stress	No Irrigation	Stress 'A'	69.4	62.2	65.8	15.3	15.8	78.4	85.6	6.8	6.7
No stress	No Irrigation	Stress 'B'	76.8	52.4	64.6	15.5	16.7	78.8	87.0	7.6	6.0
No stress	No stress	No Irrigation	70.3	60.6	65.4	16.0	16.5	81.6	86.3	7.5	6.8
No stress	No Irrigation	No Irrigation	67.0	57.1	62.1	15.3	16.6	79.4	87.8	6.6	6.5
CD 5%			N. S.	8.1	7.4	N.S.	N.S.	N.S.	N.S.	N.S.	1.2

No stress — *Irrigation applied at 0.7 atm. tension at 22.5 cm soil depth*
Stress 'A' — *Irrigation applied at 0.7 atm. tension at 30.0 cm soil depth*
Stress 'B' — *Irrigation applied at 0.7 atm. tension at 37.5 cm soil depth*
N. S. — *Not significant*

TABLE 5. Effect of levels of nitrogen on yield of canes, juice quality and yield of commercial cane sugar (CCS)

Levels of nitrogen	Yield of millable canes (t/ha)		Mean	Sugar contant (%)		Puirty coefficent (%)		Commercial cane sugar (CCS) (t/ha)	
(kg N/ha)	1974-75	1975-76		1974-75	1975-76	1974-75	1975–76	1974-75	1975-76
60	65.6	51.0	58.3	16.4	16.5	83.1	86.8	7.2	5.8
120	74.9	62.0	68.5	15.4	16.4	79.3	87.5	5.7	7.0
180	79.8	75.4	77.6	14.5	16.2	76.9	87.0	7.4 1	8.4
CD 5%	8.6	3.8	2.8	0.4	N.S.	2.1	N. S.	N.S.	0.4

TABLE 6. Effect of levels of nitrogen on yield of canes, juice quality and yield of commercial cane sugar (CCS)

Soil moisture stress			Total number of Irrigations		Consumptive use of water (mm)		Water use efficiency	
Stage I Establishment and tillering (pre-monsoon)	Stage II Grand Growth (monsoon)	Stage II Maturation (Post monsoon)	1974-75	1975-76	1974-75	1975-76	1974-75	1975-76
No stress (7)	No stress (2)	No stress (2)	13	11	1186.6	1262.3	64.3	58.8
Stress 'A' (3)	No stress (2)	No stress (2)	9	7	1003.6	1053.3	76.1	67.2
Stress 'B. (3)	No stress (2)	No stress (2)	9	7	1003.6	1053.3	71.6	68.1
No stress (7)	No Irrigation (0)	No stress (2)	11	11	1049.6	1112.1	75.4	57.0
No stress (7)	No Irrigation (0)	Stress 'A' (1)	10	10	1012.6	1112.1	68.5	57.0
No stress (7)	No Irrigation (0)	Stress 'B' (1)	10	10	1012.6	1112.1	75.8	50.0
No stress (7)	No stress (2)	No Irrigation (0)	11	9	0038.6	1053.3	67.6	56.3
No stress (7)	No Irrigation (0)	No Irrigation (0)	9	9	910.6	1008.1	73.5	57.3

Soil-moisture studies

Consumptive use of water:

The rate of water use was lower in dry regime than in moist and wet regimes. (Table 6). Soil moisture regimes had an appreciable effect on consumptive use. It increased from 1004 mm from stress 'A' and 'B' to 1187 mm under no stress during 1974-75 and 1053 to 1262 in 1975-76. The pre-monsoon period proved to be most decisive period because of the higher evaporative demand of the atmosphere during this time.

Water use efficiency (WUE):

The water use efficiency of water increased with restricted water supply i.e. under higher stresses indicating thereby, the higher production of cane per cm of water consumed as compared to no stress i.e. liberal water supply.

Irrigation at higher soil water stress i.e. stress 'A' and stress 'B' resulted in higher productivity per cm of water consumed as compared to no stress treatment. Nitrogen fertilization also resulted in increased WUE. This indicated that the effect of nitrogen was more on cane yield as compared to that on the consumptive use. This supports the views of Viets Jr who reported that fertilizers increase water use efficiency.

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ESTUDIOS SOBRE EL EFECTO DE LA CARENCIA DE AGUA EN EL SUELO Y NIVELES DE NITROGENO EN PLANTACIONES DE PRIMAVERA DE LA CAÑA DE AZUCAR

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RESUMEN

En el Instituto Indio de Investigación Agricola, Neva Delhi, se condujo una investigación para estudiar el efecto de la carencia de agua en el suelo, impuesta durante; 1) el periodo de pre-monzones (estado de germinacion y estabilización); 2) periodo de gran crecimiento en pleno monzón y luego en post-monzónes (estado de maduración) y 3) Tres niveles de nitrógeno, a saber, 60, 120 y 180 Kg N/ha con sus efectos sobre rendimiento y calidad del jugo. Estos trabajos se condujeron durante 2 ciclos de cosecha, en 1974-75 y 1975-76.

El suelo en el campo experimental era de textura franco-arenoso y fertilidad media. Se trabajo en ambas estaciones con la variedad Co 1148 (cultivar de larga duración y maduración tardia).

El rendimiento de caña fue adversamente afectado por la carencia de agua en el suelo por arriba de 0,70 atmosferas de tension a los 30 cm. de profunidad en cualquier estado.

Los riegos durante los turnos de sequia en epoca del monzón y uno a dos riegos en el periodo de post-monzón fueron beneficiosos.

Los aplicaciones de nitrógeno incrementaron el rendimiento de cañas molibles pero en cambio la calidad del jugo-por ejemplo contenido de sacarosa fue adversamente afectada y por último, el rendimiento de azúcar comercial tambien fue afectado en concordancia.

PHYSIOLOGICAL BASIS OF YIELD VARIATION BETWEEN AND WITHIN SUGARCANE VARIETIES GROWN UNDER CONTRASTING ENVIRONMENTS
I. COMPONENTS OF SUCROSE YIELD AT HARVEST

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ABSTRACT

Four commercial varieties of sugarcane were sown at different dates during the planting season under contrasting environments. All were harvested at a fixed age of 68 weeks. Sucrose yield variation at harvest was analyzed in terms of its components; tiller density, tiller dry weight and sucrose concentration (sucrose % dry weight). The variation in sucrose yield at harvest was due to wider variations in biological yield as compared to sucrose concentration. Tiller density was found to be a major yield determinant. The effect of site and planting date indicated that warm conditions favored dry matter accumulation while cool conditions increased sucrose accumulation. High sucrose yield at harvest among the varieties was associated with biological yield in a low tillering and high stalk dry weight variety.

Varietal differences in sucrose yield were affected by both site and planting date indicating possible varietal adaptation. However, sucrose concentration characteristic of varieties was not drastically affected by site or planting date. Varietal adaptation was attributed to both tiller density and stalk dry weight. The absence of large differences in stalk weight or sucrose concentration at harvest between tillers of different ages showed homogeneity of the population of surviving tillers and that the late tillers were able to compete with the early ones. Treatment effects on plant morphology as related to physiological attributes are discussed in relation to yield maximization.

INTRODUCTION

In a number of countries where sugarcane is grown, the planting and harvesting periods extend over several months. The sequences of climatic conditions during the year are such that the sugarcane is not always sown under optimal conditions for germination and tillering. In Mauritius, the planting season extends from March up to August while harvesting is done between June and December.

It is accepted that a knowledge of the physiological basis of yield variation

in any crop is a pre-requisite for the formulation of strategies for increases in yield at harvest (Watson[12]). The achievement for different crops have been summarized recently (Evans[3]). Up to now very few studies have been carried out on growth and developmental aspects of the sugarcane plant under field conditions. Studies undertaken in South Africa, Guyana and the West Indies have already been reported (Gosnell[4], Mc Lean *et al*[8], Mc Coll[7]). These reports indicated a need for information on the behavior of sucrose yield components during the crop cycle so as to relate them to yield variation observed at harvest.

In crops such as wheat or rice, similar economic yields at harvest may be achieved through different combinations of two or more components. In the above crops, such components are: number of productive tillers per unit area, grain number and grain weight (Evans[3]). In sugarcane, the components of sucrose yield are the number of stalks (tillers or shoots) per unit area, their average weight and sucrose concentration (sucrose % dry weight).

Studies on the physiological basis of yield variation in sugarcane were initiated in Mauritius in 1973. Growth and developmental aspects of four commercial varieties grown under contrasting environments were studied in a plant cane and ratoon crops. The results on sucrose yield at harvest in the plant cane crop are dealt with in this paper and those on the tillering aspect are presented in the subsequent one.

MATERIALS AND METHODS

A 4 x 4 factorial design with three replicates was used in this study. Four commercial varieties (M 13/56, M 351/57, S 17 and M 93/48) were planted at four different dates at equal intervals. The same design was used in all three sites (Pamplemousses, Trianon and Alma). Variety M 13/56 is high tillering with thin stalks and narrow leaves; M 93/48 is low tillering but has thick stalks and broad leaves. Variety M 351(57 is similar to the latter but has a poor sucrose concentration. Variety S 17 is intermediate in plant habit but has a high sucrose concentration at harvest.

Some characteristics of the three sites are given in Table 1.

TABLE 1. Characteristics of the three sites

Site	Altitude (m)	Mean Annual rainfall (mm) (based on 30 years)	Soil type
Pamplemousses	79	1494	Low Humic Latosol
Trianon	305	1589	Low Humic Latosol
Alma	442	3126	Humic Ferruginous Latosol

The first sowing was done in March ,1973 and the three subsequent ones at eight weeks interval (referred to as April, June and August planting date treatments, respectively). Each plot consisted of 10 rows at 1.6 meters wide and 8 meters long. All three sites were rainfed.

The primary shoots which emerged after planting in each treatment were tagged with paint in four border rows on each side. These shoots were referred to as 'early' tillers. Tiller emerging within the following 7 or 8 weeks were also tagged with a different paint mark and referred to as medium or mid-season tillers. All other tillers emerging later were not marked and referred to as 'late' tillers.

Each planting date treatment was harvested at 68 weeks at the three sites. At harvest, the number of stalks in each group was recorded in each row (tiller group density was derived from the records). A random sample (12 stalks) of each group of stalks was taken to the laboratory to determine stalk height and internode number, leaf fresh weight, stalk fresh weight, pol % cane (sucrose % fresh weight) of stalk sample (de Saint Antoine[10]), fibre % cane (de Saint Antoine and de Froberville[11]) and Brix % cane.

Samples of leaf and leaf sheath were dried to constant weight (48 hours at 80°C in a ventilated oven) to determine dry weight. A separate sample of one meter row length including all three groups of tillers were analyzed separately for average stalk dry weight and sucrose concentration. Using above data, the following variables were calculated: stem dry matter content (fiber % cane + Brix % cane); Sucrose per stalk; total stalk dry weight (stem + leaves + leaf sheaths); sucrose concentration (sucrose % stalk dry weight). Tiller density, total crop dry weight, sucrose yield per unit area and per average stalk were also calculated as well as the sucrose concentration, dry weight, length and internode number for each group of tillers.

RESULTS

Planting date, site and variety were responsible for the significant variation in sucrose yield at harvest. The variation observed for site and planting date could be explained by more pronounced differences in crop dry weight as compared to sucrose concentration which was also responsible for the varietal differences.

Treatments main effects on sucrose yield and its components are illustrated in Fig. 1. Among the three sites, a higher sucrose and crop dry weight yields were observed at the warmer site, Pamplemousses, than at Alma where the climate was cooler. The difference in crop dry weight between these two sites was more pronounced than for sucrose yield due to a lower sucrose concentration at Pamplemousses as compared to that of Alma. The pronounced crop dry weight difference is explained by tiller density differences (Fig. 1) and also by a lower stalk dry weight at Alma only.

Sugar yields were similar and significantly higher in the first two plantings

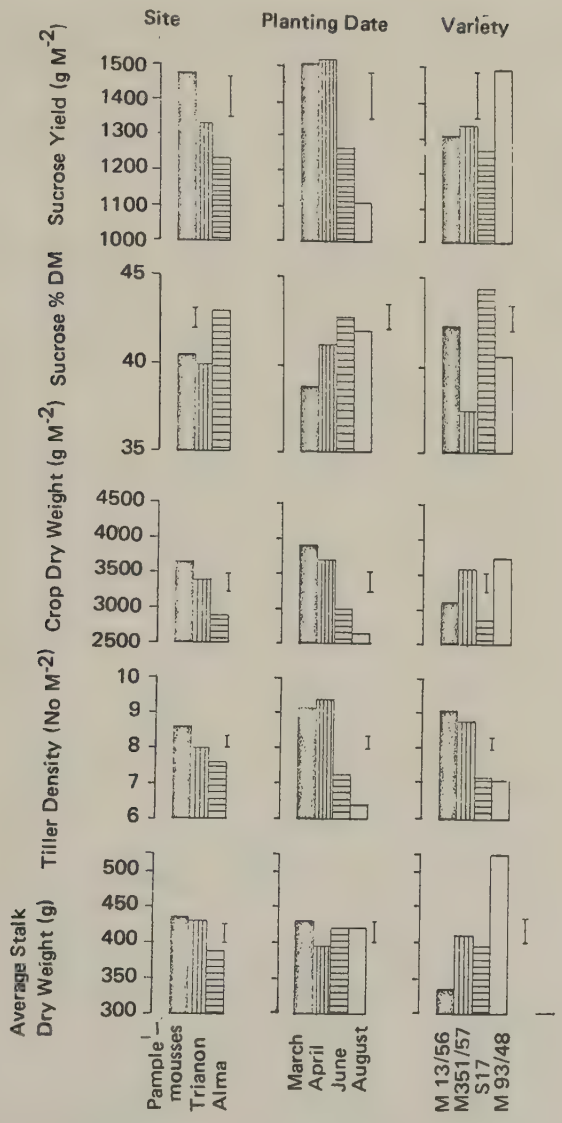

FIGURE 1. Effect of site and planting date on sucrose yield over its components in four sugarcane varieties.

dates as compared to the later ones. Once again, the differences were due to higher crop dry weights but not to higher sucrose concentration in the earlier plantings and tiller density was solely responsible for crop dry weight differences (Fig. 1).

The thick stalk varieties (M 93/48, M 351/57) reached harvest with the highest sucrose and dry weight yields but with the lowest sucrose concentration.

In contrast with planting date effect, dry weight yields variation for varietal effect was due more to stalk dry weight component than to tiller density (Fig. 1).

A significant interaction between site and planting date was observed for sucrose yield as could be explained by the high dry weight yield obtained from April sowing at Pamplemousses and which could be attributed to higher tiller density. (Table 2).

TABLE 2. Mean* sucrose, dry weight, pol % DM, tiller density and average stalk weight of four planting dates at three sites.

Site	Planting date	Sucrose gm^{-2}	Dry wt. gm^{-2}	Pol % DM **	Tiller no. m^{-2}	Stalk dry wt. g
Pamplemousses	Mar. 5	1424 b	3870 b	36.4 b	93 b	420 a
	Apr. 30	1947 a	4670 a	41.9 a	112 a	421 a
	June 25	1436 b	3440 b	41.9 a	75 c	466 a
	Aug. 20	1095 c	2615 c	41.9 a	62 d	430 a
Trianon	Mar. 5	1687 a	4462 a	38.1 b	94 a	487 a
	Apr. 30	1228 b	3225 b	38.2 b	87 b	374 c
	June 25	1318 b	3276 b	40.6 a	78 c	428 b
	Aug. 20	1111 b	2641 c	42.4 a	62 d	429 b
Alma	Mar. 5	1410 a	3407 a	41.6 b	88 a	389 a
	Apr. 30	1365 a	3160 ab	43.1 b	83 a	389 a
	June 25	1045 b	2301 bc	45.7 a	65 b	363 a
	Aug. 20	1116 b	2715 b	41.5 b	67 b	405 a
LSD P 0.05		228	488	2.4	6	52

Different letters denote significant difference between planting dates at P 0.05

* *Mean of four varieties*

** *Sucrose concentration*

The performance of the varieties was not similar at all sites and resulted in a significant interaction. Varieties M 13/56 and M 93/48 have, thus, similar and highest yields at Pamplemousses while the former was the lowest at the other two sites (Table 3). It should be noted that the high tillering characteristic of variety M 13/56 was compensated for its low stalk dry weight only at Pamplemousses. The good performance of variety S 17 at Trianon could be ascribed to both its crop dry weight and sucrose concentration. Although crop dry weight of S 17 and M 13/56 were similar at Alma, the sucrose yield of the former was better on account of its high sucrose concentration (Table 3).

Interactions between varieties and planting date were generally low for all characters measured except for the overall poor performance of S 17 when plant-

TABLE 3. Mean* sucrose, dry weight, pol % DM, tiller density and average stalk weight of four varieties at three sites

Site	Variety	Sucrose gm^{-2}	Dry wt. gm^{-2}	Pol % DM **	Tiller no. $10\ m^{-2}$	Stalk dry wt. g
Pamplemousses	M 13/56	1682 a	3926 a	43.0 a	105 a	375 b
	M 351/57	1318 b	3705 a	35.1 c	89 b	421 b
	S 17	1269 b	2925 b	43.1 a	73 c	402 b
	M 93/48	1633 a	4041 a	40.5 b	75 c	539 a
Trianon	M 13/56	1173 c	2915 b	40.6 b	88 a	328 c
	M 351/57	1355 bc	3694 a	37.0 c	86 a	427 b
	S 17	1401 ab	3147 b	44.6 a	74 b	428 b
	M 93/48	1416 ab	3847 a	37.2 c	72 b	534 a
Alma	M 13/56	1058 c	2470 b	42.9 b	80 b	306 c
	M 351/57	1324 ab	3352 a	40.2 c	88 a	378 b
	S 17	1120 bc	2457 b	48.4 a	69 c	356 b
	M 93/48	1434 a	3304 a	43.5 b	69 c	505 a
LSD P 0.05		228	488	2.4	6	52

Different letters denote significant difference between planting date treatments at P0.05

* *Mean of four planting dates*

** *Sucrose concentration*

TABLE 4. Tiller group density ($10\ m^{-2}$) at the three sites

Site	Planting date	Tiller type		
		Early	Middle	Late
Pamplemousses	Mar.	25 a	20 b	50 b
	Apr.	16 c	32 a	64 a
	June	21 b	23 b	31 d
	July	10 d	15 c	37 c
Trianon	Apr.	9 a	9 a	69 a
	June	8 a	7 a	62 b
	July	7 a	6 a	50 c
Alma	Apr.	12 a	13 a	58 a
	June	9 b	13 a	43 c
	July	7 c	10 a	50 b

* *Different letters denote significance between planting dates at P0.05*

TABLE 5. Mean internode number, height and stalk dry weight of tiller groups at three sites.

Site	Planting date	Internode no. per stalk			Height (cm)			Stalk dry weight (g)		
		Early	Medium	Late	Early	Medium	Late	Early	Medium	Late
Pamplemousses	Mar. 5	23.3 a	24.7 a	18.3 b	192 c	212 a	163 c	374 c	354 b	250 c
	Apr. 30	23.7 a	23.3 a	19.3 ab	205 b	186 c	181 b	378 c	336 bc	332 b
	June 25	24.1 a	21.6 b	19.8 a	223 a	200 b	201 a	461 a	368 a	367 a
	Aug. 20	23.8 a	20.1 b	18.7 ab	192 c	176 d	158 c	414 b	390 a	330 b
Trianon	Apr. 30	22.5 a	20.3 b	20.1 a	217 a	207 a	210 a	341 a	323 b	344 b
	June 25	20.2 b	20.6 b	18.9 a	173 b	186 b	173 b	339 a	359 b	303 c
	Aug. 20	23.2 a	24.2 a	20.7 a	180 b	190 b	174 b	374 a	452 a	428 a
Alma	Apr. 30	24.3 a	22.4 b	20.7 b	249 a	249 a	235 a	380 a	391 a	342 a
	June 25	21.5 b	20.8 c	20.7 b	209 b	209 b	203 b	385 a	408 a	375 a
	Aug. 20	22.9	24.2 a	23.1 a	192 c	194 c	187 c	354 a	394 a	370 a

Different letters denote significance between planting dates at P0.05.

ed in August which could be due to a low tiller density.

As indicated already, tiller density at harvest seems to be a more dominant crop dry weight determinant than average stalk dry weight. The data collected on tiller density and stalk dry weight for the three groups of tillers are presented in Tables 4 and 5. The late season group of tillers which included those emerging 12 to 13 weeks after sowing represented a larger fraction of the whole population at harvest. Variation in total tiller density particularly between planting date treatments was due mainly to variation in late tillers. The proportion of each tiller group was nearly similar within each site, except at Pamplemousses where the late group represented a lower proportion (Table 4). The same trend was observed for either the high tillering variety M 13/56 or the low tillering M 93/48.

TABLE 6. Sucrose concentration of tiller groups at the three sites

Site	Planting date	Early	Medium	Late
Pamplemousses	Mar. 5	45.2 ab	46.4 a	43.3 b
	Apr. 30	51.2 a	51.2 a	50.4 a
	June 25	51.1 a	48.2 b	49.4 b
	Aug. 20	49.9 a	48.8 a	49.5 a
Trianon	Apr. 30	48.7 a	48.6 a	48.5 a
	June 25	48.8 a	47.2 a	47.5 a
	Aug. 20	50.6 a	48.5 b	50.0 a
Alma	Apr. 30	50.0 b	50.5 ab	51.7 a
	June 25	51.4 a	48.6 b	50.6 a
	Aug. 20	50.5 a	47.6 b	48.2 b

Different letters denote significance between tiller types at P0.05

In spite of differences in number of tillers at harvest, in each group both the sucrose concentration and stalk dry weight for the tiller groups did not largely differ except for Pamplemousses where a consistently higher stalk dry weight was recorded for the early as compared to the late season group. At Pamplemousses, the late tillers of all varieties were lighter at harvest, this being more pronounced in variety M 93/48. At the same site, the early tillers for the June and August planting dates were significantly heavier than those obtained from the earlier plantings. This was also true for the medium and late tillers but the differences were less marked. Variations in stalk dry weight were generally not always proportionately related to stalk length particularly at Alma and Pamplemousses. In a similar way, differences in stalk length were not always reflected by their respective internode number.

DISCUSSION

The two main components of sucrose yield in sugarcane as well as in sugar beet are total biological yield and sucrose concentration. These two crops differ from graminaceous ones like rice, wheat or maize because their economic pro-

duct, i.e. sucrose, is a direct product of photosynthesis and is stored in their vegetative structures.

In the present studies, total biological yield for sugarcane has been considered as the product of the number of millable stalks (or tillers) and their average weight at harvest. Variation in sucrose yield at harvest was found to be due to wider variation in biological yield which was not always offset by the sucrose concentration component. In Australia, Barrie[2] found out that variation in weight of cane at harvest was five times greater than that of percentage extractible sucrose component.

Sucrose yield variation under the conditions of the present trials could be attributed to the differing climatic conditions among the three sites and within sites to the differences in climatic sequences that prevailed between sowing and harvesting of the different planting date treatments. Both site and planting date treatments affected tiller density to a larger extent than average tiller dry weight. Hence, at least in this study tiller density could be considered as the most important yield determinant. Pathway coefficient analysis applied elsewhere to yield components in random and selected sugarcane populations have also shown that stalk number was the most important component of cane yield (James[5]).

Stalk dry weight at harvest in sugarcane may be regarded as an integral of growth under the sequences of climatic conditions during the crop cycle. Within site, only a small variation in stalk dry weight was present. Hence, it seems that under local conditions, further increases in sucrose yield might be possible through an increase of sucrose concentration particularly for the early part of the harvest season and for the latter part of the season through an increase in number of millable stalks.

Among the four varieties used it was observed that high sucrose and dry matter yields were obtained, irrespective of site or planting date, from variety M 93/48 which has broader leaves and thicker stalk as compared to the others. In the results presented by Mc Coll[7], varieties with higher fresh weight per stalk at harvest also ranked among the higher sucrose yielding ones. However, in the present studies irrespective of site or planting date, variety M 93/48 had always a lower sucrose concentration than variety S 17 but a higher sucrose yield and was ranked as a low tillering variety. Therefore, further increases in sucrose yield would be possible by combining the crop dry of M 93/48 with sucrose concentration characteristic of S 17 or alternatively the high tillering habit and survival rate of variety M 13/56 with the high stalk dry weight of variety M 93/48.

The above suggestions do not represent an easy task for the breeder due to the negative relationships that exist between crop yield and sucrose concentration. Furthermore, as the sugarcane is replanted locally after at least seven years, the ratoon crop results will confirm whether the desirable characteristics in the above varieties will be maintained.

As in other countries with defined cool and warm seasons, the present results have confirmed the beneficial effect of the cool season on sucrose concent-

ration (Aughtry[1]). However, as cooler conditions do not favor dry matter accumulation or tillering, a lower crop dry weight with a higher sucrose concentration was observed at Alma (cool site) as compared to the other two sites, The results have also confirmed that irrespective of site, sucrose concentration was the limiting factor for the early part of the cropping season. Hence, the breeder's aim should be somewhat biased towards early ripening varieties such as S 17. It would be of interest to find out whether the relationship between storage tissue anatomy and sugar uptake as found by Owuru and Mc David[9] holds for such a variety. On a short-term basis the problem of low sucrose concentration at harvest may be resolved to some extent by the use of a chemical ripener (Julien *et al*[6]).

The lack of relationship between plant morphology and dry matter yield observed for the various treatments particularly when considering results for different tiller groups indicate that environment do not affect in a similar way the two above attributes. The present study has highlighted this phenomenon which requires further investigations because of its importance for varietal selection.

Differences in sucrose concentration between tiller groups were small or absent and suggest that age has little influence on dry matter partitioning and sucrose accumulation. In some instances, particularly for the mid-season plantings, the populations were also homogenous for stalk dry weight. This suggests that the late tillers are able to compete with earlier ones and must have had a higher growth rate as they reached harvest within a shorter time. Further studies are necessary to determine whether the above is due to an age effect *per se* or is related to difference in leaf area ratio. However, in some treatment combinations where there were differences in stalk dry weight between tiller groups, stalk age appears to have played a more dominant role. The relationship of the above variations to the rate/duration of tillering will be presented in a subsequent paper.

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BASES FISIOLOGICAS DE LA VARIACION DE RENDIMIENTO ENTRE Y DENTRO DE VARIEDADES DE CANA

1. Componentes de Rendimiento de Sucrosa a la Hora de Cosechar.

G.C. Soopranarien y M.H.R. Julien

RESUMEN

Cuatro variedades comerciales plantadas en diferentes tiempos durante la temporada de plantar cana bajo ambientes contrastados se cosecharon a un tiempo fijo de 68 semanas. La variacion de sucrosa al tiempo de cosechar fue analizado en sus componentes: densidad de retoños; peso seco y concentracion de sucrosa (sucrosa % peso seco) del retoño. La variacion del rendimiento de sucrosa al (cosechar) fue debido a variaciones mas amplias en rendimiento biologico opuesto a la concentracion de sucrosa. La densidad de retoño se descubrio como el mayor determinante de rendimiento. Tratamiento del sitio asi como de la fecha de plantar ha indicado que condiciones calidas favorecieron la acumulacion de materia seca mientras que condiciones frias o frescas

fomentaron la acumulacion de sucrosa. El alto rendimiento de sucrosa a la hora de cosechar entre las variedades fue asociado con rendimientos biologicos en la variedad de bajo retoño y peso seco de los troncos. Diferencias entre variedades en el rendimiento de sucrosa fueron modificadas juntamente por el sitio y la fecha de plantar indicando adaptacion posible de variedades.

La caracteristica de concentracion de sucrosa de las variedades no se modificaron drasticamente por el sitio o por tratamientos de la fecha de plantar. Adaptacion de variedades fue atribuido juntamente con la densidad de retoño como al peso seco del tronco. La ausencia de grandes diferencias en el peso seco del tronco o de la concentracion de sucrosa a la hora de cosechar entre retoños de diferentes edades mostro homogenidad de la populacion de los retoños que supervivieron y que los que se formaron mas tarde pudieron competir con los primeros. Se discuten los efectos de tratamiento en plantas morfologicas relacionadas a atributos fisiologicos en relacion a la maximinacion de rendimiento.

PHYSIOLOGICAL BASIS OF YIELD VARIATION BETWEEN AND WITHIN SUGARCANE VARIETIES GROWN UNDER CONTRASTING ENVIRONMENTS

II. THE EVOLUTION OF TILLER DENSITY IN RELATION TO YIELD AT HARVEST

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ABSTRACT

Tiller turnover differences in four commercial varieties sown under contrasting environments were followed from sowing up to harvest. Three different phases were recognized from the patterns observed. Tiller production was the dominant feature of the first phase which culminates in a peak tiller number stage. During the second phase, tiller death was predominant and leads to the achievement of a stable population (third phase) which survives up to harvest. Environmental effects were seen through differences in rates and duration of tiller production in the initial phase. Peak tiller number stage was closely related to the number of millable stalks observed at harvest. Higher tiller production irrespective of environmental conditions or variety led to higher number of stalks at harvest inspite of differences in tiller mortality. Changes within and between stalk populations are discussed in relation to a crop phasing strategy aimed at yield increases at harvest.

INTRODUCTION

Sucrose yield at harvest represents an integral of plant growth and development over the whole crop cycle. In some countries the cycle may be as short as 9 to 12 months while in others it may be as long as 20 to 24 months and even 36 months. Numerous studies have been carried out on photosynthesis, sucrose synthesis and the accumulation process in the sugarcane (Alexander[1]). However our knowledge on growth and developmental aspects of this crop has not kept pace with the physiological and biochemical studies undertaken under controlled conditions. The lack of information on sugarcane growth is quite obvious when the stage of mathematical models for other crops is compared (Evans[4], Thornley[9], Bull and Tovey[3]). Studies on growth and developmental aspects on the sugarcane were undertaken in Mauritius since 1973 and results on sucrose yield variation and yield components have already

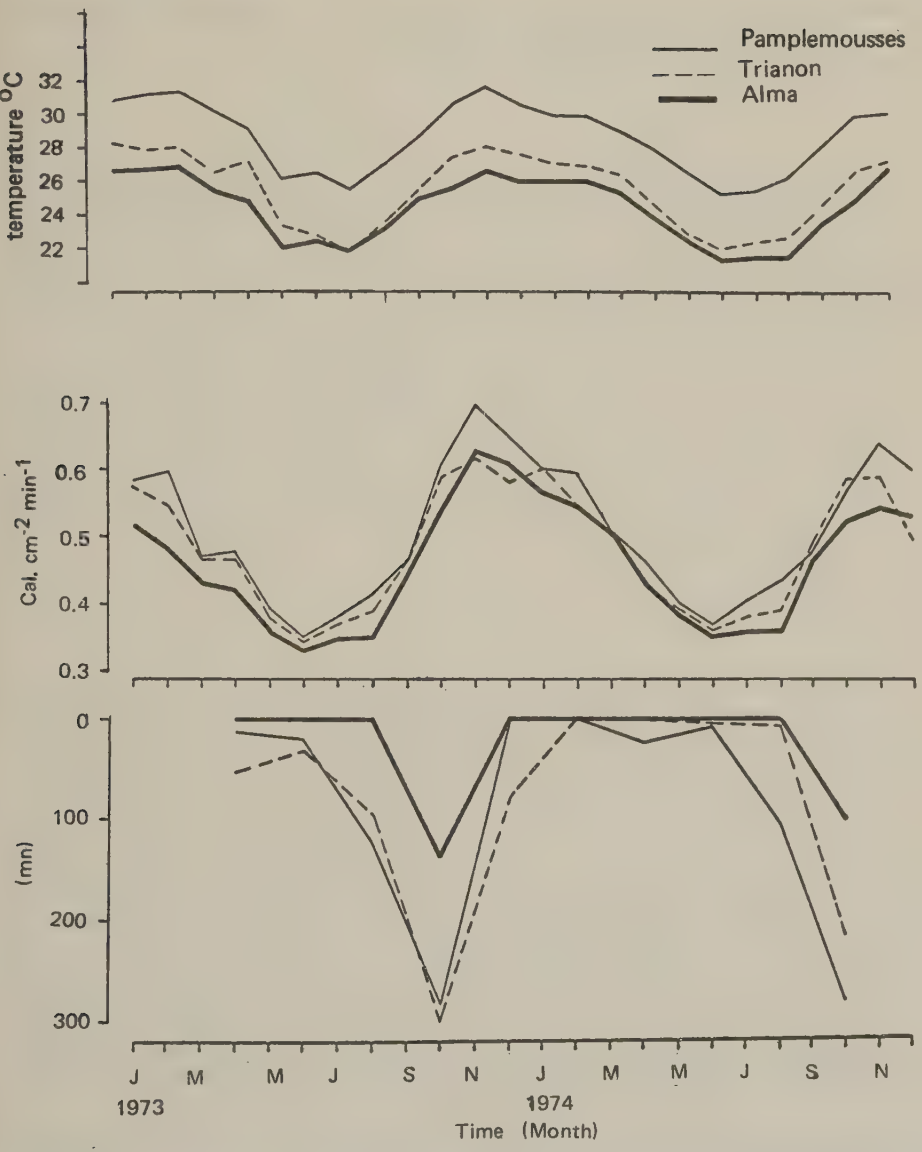

FIGURE 1. Temperature, solar radiation, and soil moisture deficit from sowing up to harvest at the three sites.

been presented (Soopramanien and Julien[7]). It was found that sucrose yield at harvest was influenced by environmental conditions and the variety grown. In general high crop dry weight at harvest irrespective of variety or planting date was not accompanied by high sucrose concentration. Tiller density was found to be a more important yield determinant than stalk dry weight or sucrose concentration. Hence, the present report deals with the changes within

and between sugarcane populations from sowing and up to harvest in relation to the number of millable stalks finally obtained.

MATERIALS AND METHODS

The experimental design, treatments, characteristics of experimental sites and varieties used have already been given in a previous paper (Soopramanien and Julien[7]). The tagging of different tiller types have also been described. Tiller counts in the four experimental rows were done at regular interval (8 weeks) up to harvest (68 weeks). The number of dead shoots (attacked by borers *Argyroploce schistaceana* Sn. and *Sesamia calamistis* Hamps. or otherwise) was also recorded for each tiller group and removed by means of a penknife so as to avoid double counting. Thus for each occasion the following number of tillers per unit area (m^2), were obtained: total tillers emerged, live early tillers, live mid-season tillers and live late-season tillers. Statistical analysis was carried out on the data for each occasion and each site separately. Data on environmental parameters between sowing and harvest are presented in Fig. 1.

RESULTS

From the patterns obtained for the evolution of total tillers which emerged and survived three phases may be recognized (Fig. 2). During the initial phase which starts sowing, tiller emergence is the main feature and an increase in tiller density is observed. After a certain period, tiller mortality sets in and gradually tiller emergence slows down as well. Thus the total tillers emerged finally reaches a maximum while the surviving ones or live tillers show a peak number stage. During the second phase as tiller mortality increases and tiller emergence is practically nil, a decline in live tiller density is observed. This second or decline phase ends when a more or less stable population stage is reached, i.e., when tiller mortality becomes insignificant and this represents the start of the third or final phase which ends at harvest. In general the results show that environmental conditions as seen through site and planting date treatments have a pronounced influence on rate and duration of tiller production and this pertaining mainly to the first phase.

Thus, a slightly lower rate of tiller production was observed at the cooler site, Alma, as opposed to the warmer ones, Pamplemousses and Trianon. However over the four planting dates a higher rate of tiller production was observed at Trianon and this resulted in a higher total tiller density at that site. It should be noted that for the August planting a lower rate was observed at Pamplemousses as opposed to Alma (Fig 2). This may be associated to the dry spell at the former site during the months of September to November.

Due to different climatic sequences, which prevailed after each planting date treatment, the time to reach peak tiller number stage varied both within

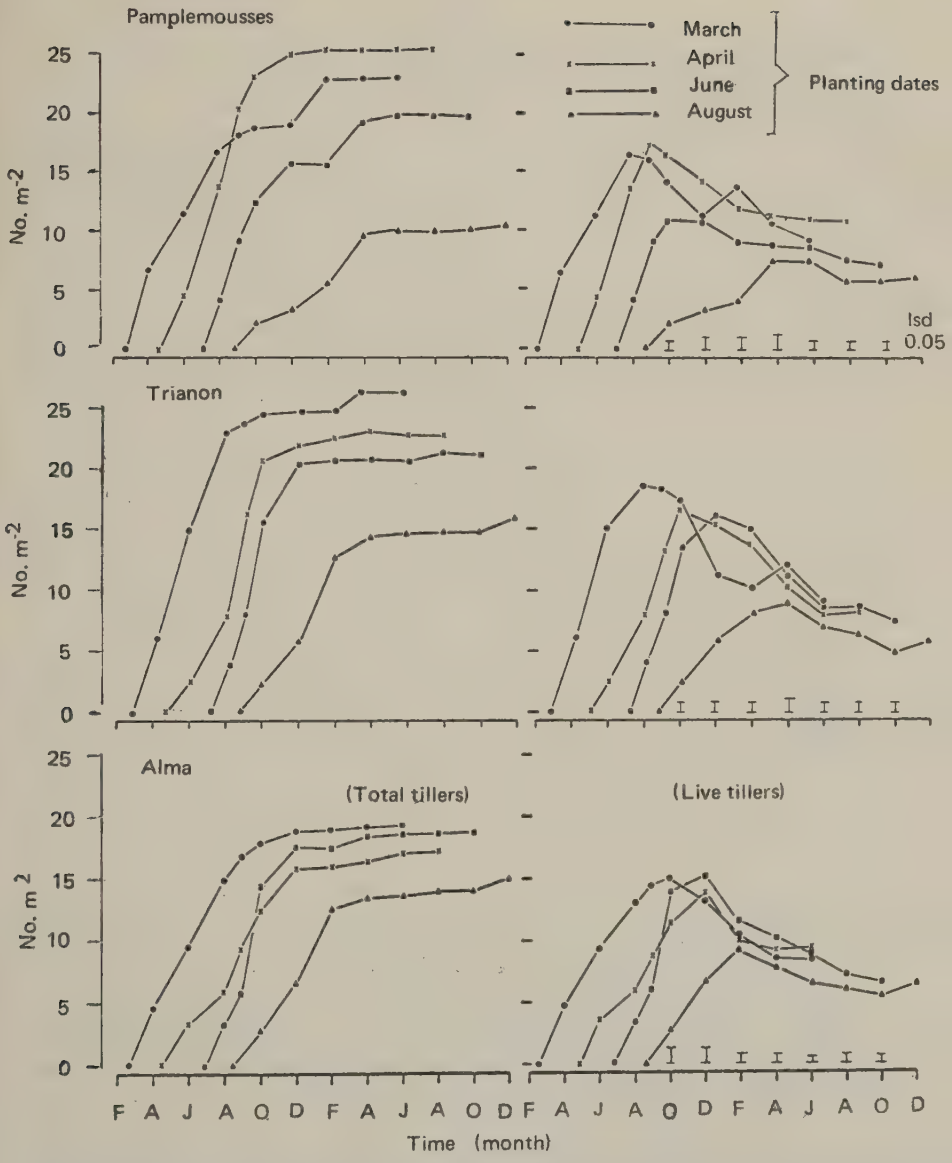

FIGURE 2. Evolution of total and live tillers in four planting date treatments at the three sites.

and between sites. At both Pamplemousses and Alma peak total tiller density was observed for the first three planting dates in the month of December; rates of tiller production was highest in June treatment, intermediate in April and lowest in March. The August treatment reached the same stage in the month of February at Alma and Trianon and two months later at Pamplemousses. On the other hand, at Trianon for the first three plantings similar

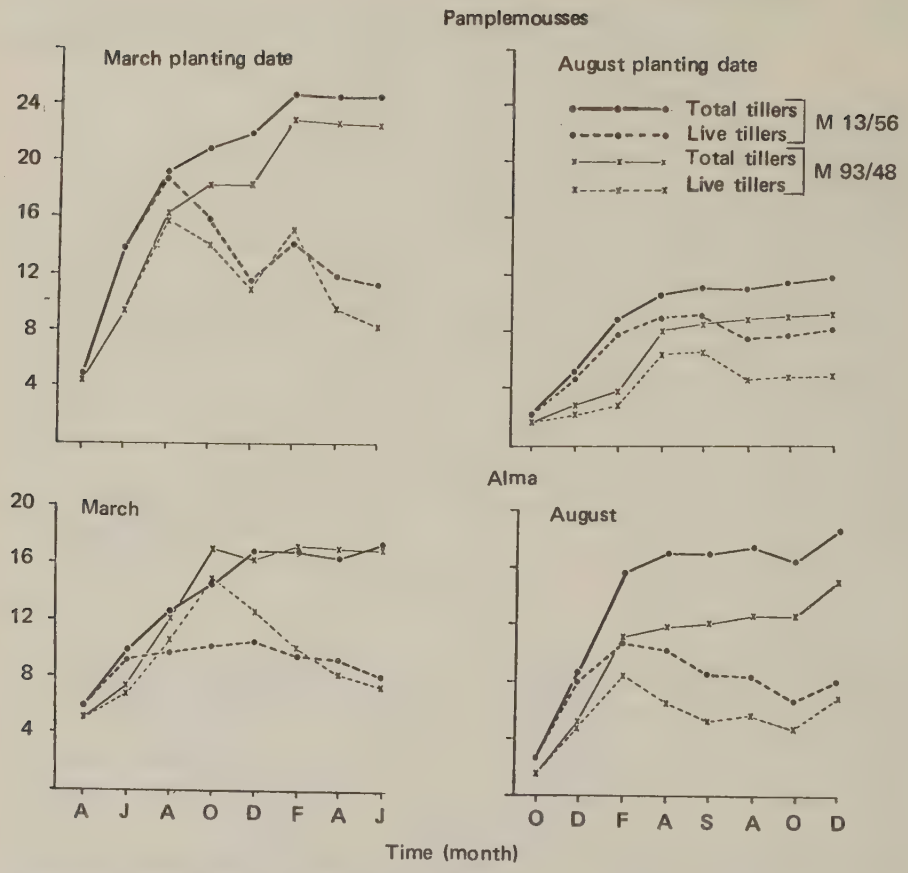

FIGURE 3. Evolution of total and live tillers in varieties M 13/56 and M 93/48 sown in March and August at Pamplemousses and Alma.

rates of tiller production were observed, peak tiller number stage was reached after similar durations and rate of tiller production was similar within that site as opposed to Pamplemousses.

Among the three sites and irrespective of planting date tiller mortality ranged from 55 at Alma to 75% of the total tillers emerged at Pamplemousses. Hence, a higher tiller mortality is associated with higher tiller production. Also within site the higher number of tillers emerging in the first three sowings as compared to the last one (August) was accompanied by a higher tiller mortality. Inspite of higher tiller mortality in the earlier sowings as opposed to the last one, the number of surviving tillers were still higher in the earlier plantings. Tiller mortality during the second phase is influenced largely by the total density achieved and to some extent by environmental conditions particularly prolonged soil moisture deficit.

During the third phase a more or less stable tiller population was maintained except at Alma where a gradual decline was observed for both the June and August plantings. For the June planting at that site, tiller mortality during that phase contributed further to the differences observed at harvest particularly with respect to the April treatment. Thus, in the month of December a higher live tiller density was observed in the June treatment as opposed to the April treatment but the converse being recorded at harvest. The effect of soil moisture deficit on an established population was observed at the warmer sites, in the March planting date treatment. A sharp drop in live tiller number was observed in that treatment prior to the month of December, this being followed by a rise representing the of late shoots. The occurrence of late shoots was also apparent prior to harvest (in the month of December) in the August treatment at both Alma and Trianon.

From the patterns observed for the four varieties, M 13/56 showed a higher tiller production rate and reached harvest also with a higher tiller density than variety M 93/48. Variety M 351/57 was nearly similar to M 13/56 while S 17 showed an intermediate behavior. In general the higher peak total tiller density observed for variety M 13/56 could be associated with a higher rate of tiller production in the early phase (Figure 3). In most occasions both varieties reached peak total tiller density stage nearly simultaneously. In some instances variation in tiller mortality was responsible for the difference observed at peak stage not being maintained at harvest. For example at Alma in the August planting a large difference was observed between the two varieties M 13/56 and M 93/48 at peak stage, this was followed by a more pronounced tiller death in variety M 13/56 which was largely responsible for the absence of a significant difference between them at harvest.

As a result of the method adopted to separate the tillers into three groups, the late group represented a larger fraction of the total population at harvest. Hence to a large extent the differences observed at harvest for total millable stalks could be ascribed to variations in production and death rates in the late group of tillers (Fig. 4). Also the early and mid-season groups reached the stable phase almost sequentially and again for these two groups higher tiller densities were accompanied by higher mortality. The effect of the prolonged soil moisture deficit on tiller turnover observed in the March planting at Pamplemousses was primarily due to higher mortality rates during the months of August to December in the mid and late season groups. Tiller death was followed by an upsurge of new shoots i.e. late tiller group (Fig. 4). This flush of tillers was followed by a nearly similar mortality.

The difference in tiller density between Alma and Pamplemousses mentioned above for the August planting date is also explained by a lower tiller production rate during the dry period at Pamplemousses as compared to Alma. Hence slightly higher tiller densities were observed at the latter site for both the early and mid-season groups of tillers. Large differences were observed between the two sites for the late tiller group in favor of Alma. However due to a

more pronounced tiller death there, a less pronounced difference in the tillers was observed at harvest.

The variations observed for total tillers among the four varieties were again due to variations in tiller mortality within each group. As observed for the site and planting date treatments, tiller production and death in the late group was largely responsible for the varietal differences. However, in only a few instances a more pronounced tiller mortality in the early group for variety M 13/56 was responsible for smaller varietal differences.

DISCUSSION

In a previous paper (Soopramanien and Julien[7]) it was indicated that tiller density was an important yield determinant in the sugarcane. The general pattern of tiller production observed in the present studies is similar to that observed elsewhere for the sugarcane or graminaceous crops such as wheat and rice (Evans[4]).

In sugarcane only a fraction of the total number of tillers produced reaches harvest. Tillering is influenced by both the variety and environmental conditions. Tiller death is due to both inter-tiller competition which is related to the micro-climate within the crop and the attack of pests and diseases

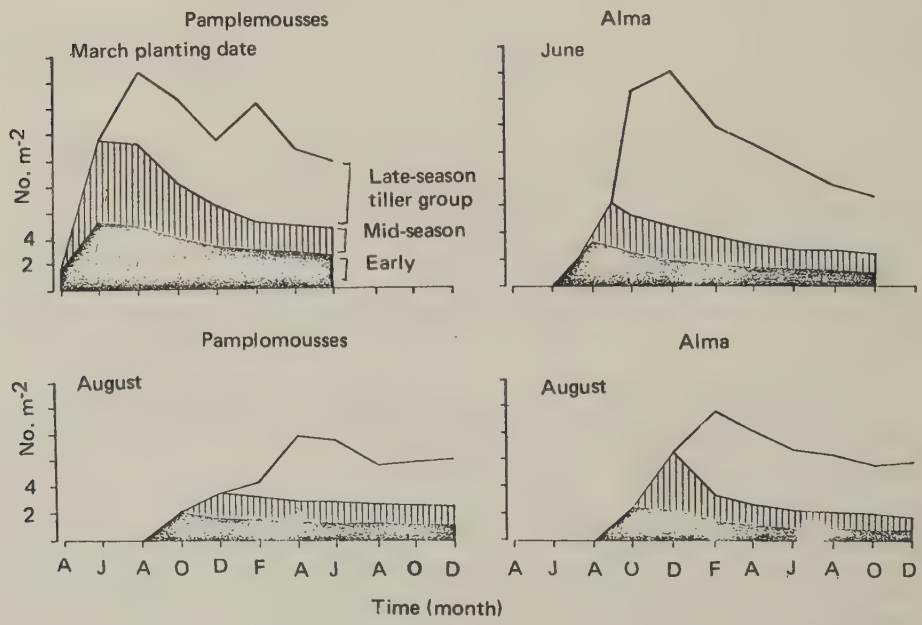

FIGURE 4. Evolution of three tiller groups for the March and August plantings at Pamplemousses and for the June and August ones at Alma.

(Van Dillewijn[10]). With the results obtained the changes in tiller population may be divided into three distinct phases with stages that may be considered as yield determining ones. In the first or initial phase after planting, tiller emergence is the predominant feature while tiller death is absent or insignificant. The first phase culminates in a peak tiller number stage which is closely related to the final tiller density at harvest. Site and planting date treatments have indicated a pronounced environmental effect on the first phase through the effects on rate and duration of tiller emergence. Thus a more rapid tiller production with a shorter duration of the first phase was observed at the warmer site as opposed to the cooler one and similarly for the warm and moist planting date treatment (March) as opposed to the cool and dry one (August).

Tiller death in the present studies was observed prior to the peak tiller number stage and during the second phase. It is the dominant feature while tiller emergence is virtually nil. The extent of tiller death was associated with the density achieved at peak tiller number stage. Under local conditions, it was found that 30 to 50% of total tillers that emerged reached harvest. This is in agreement with the findings of other workers with different varieties of sugarcane or even wheat (Thompson and Du Toit[8], Bull and Glasziou[2], Evans *et al*[5]). Evidence has been presented to the fact that tiller death involves to a large extent the late-formed or late-season tillers. This observation in the sugarcane as well as in wheat has been attributed to the inability of the late tillers to compete for light and nutrients within a dense canopy (Van Dillewijn[10], Rawson and Donald[6]). As the sugarcane shoot borer contributed towards tiller death, it is not known whether a higher tiller survival could have resulted in their absence. The second phase culminates in a more or less stable population being established. Through the effects of environmental conditions on tiller production and mortality, different proportions of each group of tillers were observed at the beginning of the third phase. The absence of large differences in stalk dry weight between early and late season tillers inspite of their age difference at harvest (Soopramanien and Julien[7]) suggests that stalk growth rate and development is low during the first and second phase of tillering. Further, it also indicates that more attention should be paid to dry matter accumulation and partitioning in the third phase as stalk dry weight at harvest represents the integral of growth achieved by the surviving stalks during that period.

One of the inefficiencies of crop production has been ascribed to the time taken to achieve full canopy i.e. only partial energy capture during early growth (Evans[4]). For the sugarcane from a practical point of view, early canopy closure is a desirable feature for weed control. On the other hand energy captured by tillers which do not reach harvest represents a real loss. Hence for sugarcane growing areas with well defined warm and cool season, it is believed that a proper crop phasing strategy is necessary so as to achieve maximum yield at harvest. Thus the choice of varieties and planting date should be such

that a stable population of tillers is achieved at the beginning of the warm season. The results have indicated that a prolonged soil moisture deficit may cause further tiller death in an established crop. Thus if the dry spell coincides with the natural mortality phase, the losses could be reduced to some extent. Results of the ratoon crops will have to be taken into consideration prior to final conclusions and recommendations.

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BASES FISIOLOGICAS DE LA VARIACION DE RENDIMIENTO ENTRE Y DENTRO DE VARIEDADES DE CAÑA CRECIDOS BAJO AMBIENTES CONTRASTADOS

G. C. Soopramanien and M. H. R. Julien

RESUMEN

Diferencias en la vuelta de retoños en cuatro variedades comerciales plantadas bajo ambientes contrastados se siguieron desde el plantar hasta el cosechar. Tres diferentes etapas se reconocieron de los patrones observados. La reproducción de retoños fué la facción o característica dominante de la primera etapa que culminó en un estado mayor en el número de retoños. Durante la segunda etapa, la muerte de retoños predominaba y conduce al logro de una populacion estable (3ª etapa) que sobrevive hasta el tiempo de cosechar. Efectos en el ambiente se vieron por medio de diferencias en la rapidez y la duración de la producción de retoños en las etapas iniciales. El estado mayor de números de retoños fué relacionado íntimamente al número de retoños molibles observados al cosechar. Mayor producción de retoños irrespectivas a condiciones de ambiente o de variedad condujo a un mayor número de troncos al cosechar, a pesar de diferencias en la mortalidad de retoños. Cambios dentro y entre la población de troncos se discuten en relación a la estragia de cambios de cosecha con el propósito de aumentar el rendimiento al tiempo de cosechar.

THE INFLUENCE OF GROWTH PARAMETERS AND CLIMATIC ACTORS ON EFFICIENCIES OF SOLAR ENERGY UTILIZATION IN SUGARCANE

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ABSTRACT

Field experiment was carried to find out the efficiency of solar energy utilization in relation to growth parameters and climatic factors, using seven sugarcane varieties with different plant types.

The average values of each variety of the efficiency of solar energy utilization during the whole measuring period ranged from 1.15% to 1.70% with the average at 1.44%. The highest value of the efficiency of solar energy utilization in measuring period was 4.14 percent for F 160 variety.

The efficiency of solar energy utilization was positively correlated ($r = 0.7617^{**}$) with solar radiation. It was considered that the efficiency of solar energy utilization was mainly affected by the magnitude of leaf area index in the early period of rapid growth, by net assimilation rate in the later period of rapid growth, and by the intensity of solar radiation in both growth periods.

Different values of leaf area index corresponding to the maximum values of the efficiency of solar energy utilization were observed in varieties.

INTRODUCTION

Solar radiation is the source of energy that is necessary for the dry matter production of all plants on earth. It is considered that the high productivity of crops is achieved by the improvement of the efficiency of solar energy utilization in growth processes of crop population. There are a few studies about the efficiency of solar energy utilization in sugarcane. Komutsu Ogawa and Makino obtained about 1% efficiency of solar energy utilization using POJ 2878 in 1933, in Taiwan.

The objectives of this paper are to know the change with time of the efficiency of energy utilization in sugarcane varieties, and the efficiency of solar energy utilization in relation to growth parameters and climatic factors.

MATERIALS AND METHODS

The seven varieties with different plant types were planted on September 9, 1976 in an experimental field of the Okinawa Agricultural Experiment Station. Varieties used were NCo310, NCo376, F160, F161, RK65-368, RK65-37, and IRK67-1. Sugarcane plants were grown on a fertile soil by applying standard cultural practices. All varieties received adequate fertilizer (3.75kg N, 1.87kg P_2O5, 1.87kg K_2O per $100m^2$). All varieties with one bud cutting (rayungan) were planted with a density of 1.25m x 0.2m.

Determination of the dry weight of various parts of the sugarcane plant and leaf area were made at intervals of about one month. During the growth process, samples of the stools were taken at random. The first sampling started at about two months after planting. After determination of fresh weight of various parts, the same were dried in an oven at 80^oC - 100^oC for three days.

Area of leaf blade excluding the area of leaf sheaths was measured by automatic area meter. The area of spindle leaves was also calculated from specific leaf area (SLA) of each variety. One sugarcane stool which had approximated the mean values of plant height, number of tillers, etc., to respective variety was sampled for the determination of top dry weight and leaf area.

For five stool materials, the roots were collected from soil consisting of the $0.625m^3$ volume (1.25m x 1m x 0.5m depth) and the dry weight was measured.

Climatic data obtained at an Okinawa Meteorological Observatory that is located five kilometers away from the experimental field were used. The final harvest of all varieties were made on February 1, 1978, sixty sugarcane stools were taken from a randomized block design of 6 replications.

RESULTS

The ratio of solar energy converted by a plant population as chemical energy to total incident solar energy is called "Lindeman Ratio." Change with time of the efficiency of solar energy utilization of sugarcane varieties are presented in Table 1. The equation used in the calculation of the efficiency of solar energy utilization is as follows:

$$Eu\ (\%) = \frac{H \Delta W}{\Sigma S} \times 100 \quad \text{----------(1)}$$

where H is combustion heat per one gram of dry matter (4 kcal), ΔW is the weight of dry matter increased in the period from Tn to Tn + 1 (g/m^2), ΣS is total incident short wave radiation energy ($kcal/m^2$).

The value of the efficiency of solar energy utilization during the whole

measuring period ranged from 1.15 to 1.70%, giving 1.44% as average and 4.14% as the highest value. Change with time in the efficiency of solar energy utilization increased very rapidly during the period from February of 1977 to May,1977 and reached the highest value at late May, followed by rapid decrease.

Correlation coefficient between efficiency of solar energy utilization and the four climatic factors are shown in Table 2. The efficiency of solar energy utilization was positively ($r=0.7617^{**}$) correlated with solar radiation though it was not significantly correlated with other three climatic factors.

Table 3 shows correlation coefficients between the efficiency of solar energy utilization and growth parameters calculated from average value of seven varieties. The efficiency of solar energy utilization was positively correlated with leaf area index ($r=0.7119^{*}$), and also crop growth rate ($r=0.9917^{*}$). However, no significant correlation coefficient between the efficiency of solar energy utilization and net assimilation rate and relative growth rate was established.

TABLE 1. Change with time in the efficiencies of solar energy utilization (Eu) in sugarcane varieties.

Measuring Period	Eu (%) of varieties. RK 65—37	RK 65—368	IRK 67—1	NC_o310	NC_o376	F160	F161	Mean value	Mean LAI
1976									
Nov. 9—Nov. 24	0.72	0.33	0.52	0.39	0.52	0.38	0.55	0.49	0.158
Nov. 25—Dec. 12	0.46	0.34	0.46	0.52	0.02	0.52	0.58	0.41	0.250
1977									
Dec. 13—Jan. 12	0.58	0.16	0.58	0.26	0.22	0.02	0.04	0.27	0.391
1977									
Jan. 13—Feb. 3	1.37	0.38	0.19	0.51	0.60	1.23	1.34	0.80	0.593
Feb. 4—Mar. 8	1.20	0.66	0.92	1.09	1.05	0.59	0.37	0.84	0.807
Mar. 9—Apr. 12	2.32	1.08	1.85	1.33	1.43	1.10	1.38	1.50	1.456
Apr. 13—May 9	3.03	1.17	3.83	2.56	2.17	2.68	3.33	2.68	2.729
May 10—June. 9	3.80	3.21	2.89	3.73	3.64	4.14	3.74	3.59	5.236
Jun. 10—Jul. 17	2.07	2.77	3.78	3.14	2.20	4.09	1.92	2.85	6.803
Jul. 18—Aug. 29	1.99	1.81	0.09	2.02	1.15	0.37	0.67	1.16	5.870
Aug. 30—Oct. 3	1.12	0.68	0.71	2.16	1.59	0.005	2.26	1.22	4.528
Mean value of Eu (%)	1.70	1.15	1.44	1.61	1.33	1.38	1.47	1.44	——

In order to know in detail the relation between the efficiency of solar energy utilization and growth parameters, correlation coefficients between the efficiency of solar energy utilization and growth parameters among varieties in the every measuring period are presented in Table 4. The efficiency of solar energy utilization was positively perfectly correlated with crop growth rate in almost all of seasons. The efficiency of solar energy utilization was positively ($r=0.9368^{**}$, 0.8140^{*})

TABLE 2. Correlation coefficients between the efficiencies of solar energy utilization and climatic factors.

Characters	Mean daily temperature	daily sunshine hours	Average rainfall	Daily solar radiation
Eu	0.5191	0.5758	0.1608	0.7617**
SEu	0.7365*	0.5822	0.5814	0.7304*

Eu : efficiencies of solar energy utilization for total dry matter production.
SEu: efficiencies of solar energy utilization from dry matter of stalks

TABLE 3. Correlation coefficients between the efficiencies of solar energy utilization and growth parameters.

Characters	Leaf area index	Crop growth rate	Net assimilation rate	Relative growth rate
Efficiencies of solar energy uitlization	0.7119*	0.9917*	—0.0880	—0.1836

correlated with leaf area index in the early period of rapid growth. When leaf area of sugarcane plant population kept larger LAI, the efficiency of solar energy utilization was positively correlated with net assimilation rate (NAR). In both early and later periods of growth, the efficiency of solar energy utilization correlated with relative growth rate.

Correlation coefficient matrix among maximum Eu, and mean Eu, optimum LAI and maximum LAI in the varieties was presented in Table 5. Maximum Eu was positively correlated with optimum LAI (r=D84.97*), with maximum NAR (r= 0.7722*), and also with maximum LAI (r=0.8903**) in the varieties. Optimum LAI was positively (r=0.7896*) correlated with maximum LAI. Also, maximum NAR was positively ($r=0.7293^{n.s.}$) correlated with maximum LAI, but it was statistically significant.

Table 6 shows the efficiency of solar energy utilization for dry matter of stalks that was related to economic yield. The efficiency of solar energy utilization for dry matter of stalks was 0.99% on the average. As shown in Table 2, the efficiency of solar energy utilization for dry matter of stalks was positively correlated with mean temperature (r=0.7365*), and with solar radiation (r=0.7304*).

As described above, leaf area index seemed to be the most important factor responsible for the variation of the efficiency of solar energy utilization during the early period of rapid growth in the varieties. As shown in Fig. 1, an average regression curve between the efficiency of solar energy utilization and leaf area index could be drawn till leaf area index reached the highest value. Difference among varieties was observed in the value of LAI corresponding to the maximum values

TABLE 4. Correlation coefficients between the efficiencies of solar energy utilization and growth parameters in sugarcane varieties.

Measuring Period	Efficiencies of solar energy utilization and leaf area index	Efficiencies of solar energy utilization and crop growth rate	Efficiencies of solar energy utilization and net assimilation rate	Efficiencies of solar energy utilization and relative growth rate
1976				
Nov. 9—Nov. 24	0.5159	0.9907**	0.4028	0.5858
Nov. 25-Dec. 12	0.7843*	0.9998**	0.9058**	0.9066**
1977				
Dec. 13—Jan 12	0.6212	0.999**	0.8309*	0.8994**
1977				
Jan. 13—Feb. 3	0.5463	1.0000**	0.8761**	0.8605**
Feb. 4—Mar. 8	0.4065	1.0000**	0.7552*	0.6944
Mar. 9—Apr. 12	0.9368**	1.0000**	0.5774	9.4511
Apr. 13—May. 9	0.8140*	0.9153**	0.5525	0.7597*
May. 10—Jun. 9	—0.0552	1.0000**	0.7716*	0.2743
Jun. 10—Jul. 17	0.5749	1.0000**	0.8418*	0.8458*
Jul. 18—Aug. 29	—0.4477	1.0000**	0.3892	0.9724**
Aug. 30—Oct. 3	0.0208	0.9999**	0.9833**	0.9607**

TABLE 5. Correlation coefficient matrix between maximum Eu (1) and mean Eu (2), optimum LAI(3), maximum NAR (4), maximum LAI(5) in sugarcane varieties.

Characters	Mean Eu	Optimum LAI	Maximum NAR	Maximum LAI
Maximum Eu	0.5124	0.8407*	0.7722*	0.8903**
Mean Eu		0.5683	0.0656	0.4938
Optimum LAI			0.4124	0.7896*
Maximum NAR				0.7293

(1) : Maximum of efficiencies of solar energy utilization
(2) Mean of efficiencies of solar energy utilization.
(3) : Optimum of leaf area Index.
(4) : Maximum of net assimilation rate.
(5) : Maximum of leaf area index.

of the efficiency of solar energy utilization.

DISCUSSION

The highest value (4.14%) of the efficiency of solar energy utilization in this study was considerably higher than those reported earlier on other crop species, e.g., 30% in sudangrass (Loomis and Williams, and 2.9% in maize (Williams *et al*[4]). Also, this vaiue was considerably higher than the highest value (3.32%) of rice

reported in "Maximal Growth Rate Experiments (1967-1971)" by Japanese Committee for the international Biological Program (JIBP)[2]. However this value was lower than those reported on other crop species, e.g., 4.36% in soybean, 4.63% in maize, 4.52% in sugar beet in JIBP[2].

Mean value of 1.44% of the efficiency of solar energy utilization in this study was higher than those reported on crop species in JIBP, e.g., 1.25% for lowland rice, 0.72% for soybean, 1.34% for maize, and 1.35% for sugar beet, which were average values for replication of five years.

As shown in Table 2, it was considered that the efficiency of solar energy utilization was mainly affected by the intensity of solar radiation than the photoperiod because sugarcane belonged to C4 plant. It was reported by Hesketh and Moss[1] that the photosynthesis of sugarcane was enhanced by a strong radiation.

TABLE 6. Change with time in the efficiencies of solar energy utilization for dry matter of stalks (SEu) of sugarcane varieties.

Periods of measurement	SEu (%) of varieties							Mean value
	RK 65—37	RK 65—368	IRK 67—1	NCo310	NCo376	F160	F161	
1977								
Jan. 13—Feb. 3	0.10	0.03	0.002	0.07	0.02	0.31	0.13	0.09
Feb. 4—Mar. 8	0.30	0.09	0.07	0.12	0.13	0.03	0.06	0.11
Mar. 9—Apr. 12	0.20	0.21	0.24	0.27	0.34	0.13	0.19	0.23
Apr. 13—May. 9	1.80	0.37	1.36	0.29	0.63	0.81	1.27	0.93
May. 10—Jun. 9	2.36	1.35	2.47	2.25	2.04	1.98	1.73	2.03
Jun. 10—Jul. 17	1.96	2.39	2.50	2.61	2.22	3.09	2.56	2.48
Jul. 18-Aug. 29	1.86	1.09	0.31	1.29	0.77	0.72	0.45	0.93
Aug. 30—Oct. 3	1.26	0.95	0.52	1.96	1.54	0.32	1.40	1.12
Mean value of SEu (%)	1.23	0.81	0.93	1.11	0.96	0.92	0.97	0.99

It was shown that the importance of leaf area index and net assimilation rate of sugarcane population for the efficiency of solar energy utilization would change with growth period. The efficiency of solar energy utilization was more dependent on the difference in the magnitude of leaf area index than net assimilation rate in the early period of rapid growth, but the influence of leaf area index for the efficiency of solar energy utilization was weakened in the period having larger leaf area index. On the other hand, the efficiency of solar energy utilization was mainly affected in the period having larger leaf area index by the magnitude of net assimilation rate than leaf area index.

Positive correlation, although not statistically significant, between maximum net assimilation rate and maximum leaf area index may suggest possibility of selection of varieties with higher net assimilation rate and larger leaf area index.

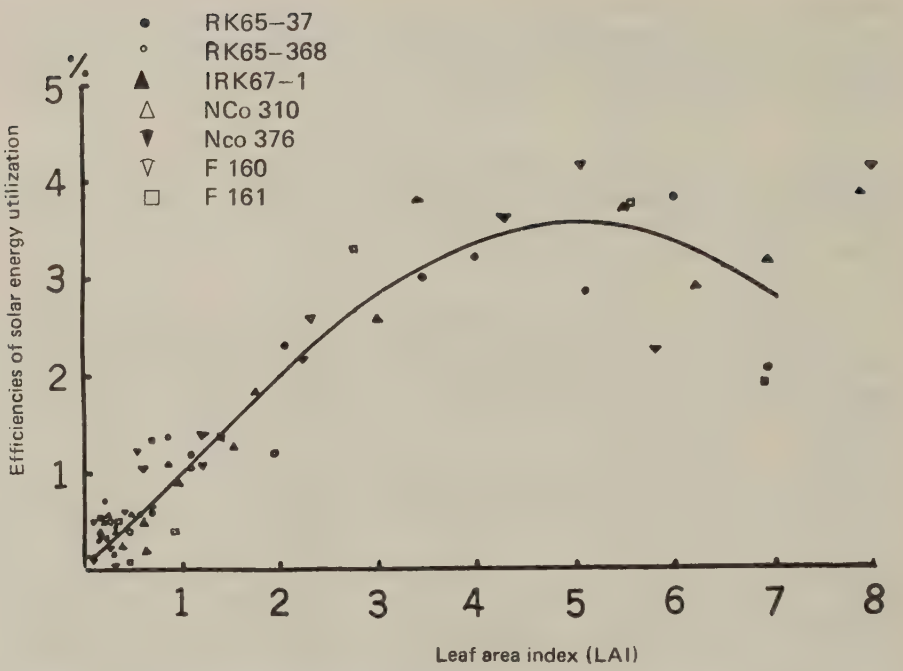

FIGURE 1. Relationship between LAI and Eu in sugarcane varieties. The regression line is for the maximum LAI.

CONCLUSION

Relationship between the efficiency of solar energy utilization and growth parameters, and climatic factor were studied in an experimental field of Okinawa Agricultural Experiment Station. Change with time of the efficiency of solar energy utilization were drawn as a parabolic curve with the average value of 1.44%.

In an analysis on relationship between the efficiency of solar energy utilization and growth parameters, a close positive correlation coefficient between the efficiency of solar energy utilization and leaf area index in the early period of rapid growth and a close positive correlation coefficient between the efficiency of solar energy utilization and net assimilation rate in the later period of rapid growth were found.

The efficiency of solar energy utilization was positively ($r = 0.7617^{**}$) correlated with solar radiation. Difference in sugarcane varieties was found in the Eu-LAI curves which had leaf area index corresponding to maximum value of the efficiency of solar energy utilization.

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LA INFLUENCIA DE PARAMETROS DE CRECIMIENTO Y FACTORES CLIMATICOS SOBRE EFICIENCIAS DE UTILIZACION DE ENERGIA SOLAR EN VARIEDADES DE CAÑA DE AZUCAR

Masaki Shimabuku, Masaaki Kudo and Koichi Tamaki

RESUMEN

Se llevaron a cabo experimentos de campo para determinar la eficiencia de utilizacion de energia solar en relacion a parametros de crecimiento y factores climaticos, utilizando siete diferentes variedades de caña de azucar.

La eficiencia de utilizacion de energia solar durante todo el periodo de medicion osciló desde 1.15 por ciento hasta 1.70 por ciento, con promedio de 1.44 por ciento.

El valor mas alto de eficiencia de utilizacion de energia solar durante el periodo de medicion fue 4.14 por ciento para la variedad F 160.

La eficiencia de utilizacion de energia solar estuvo correlacionada positivamente (r=0.7617**) con radiacion solar.

Se considero que la eficiencia de utilizacion de energia solar fue principalmente afectada por la magnitud del indice del area foliar durante el periodo inicial de rapido crecimiento, y por asimilacion neta en el ultimo periodo de crecimiento, y por la intensidad de radiacion solar durante ambos periodos de crecimiento.

Se observaron diferentes valores de indica de area foliar correspondientes a valores maximos de utilizacion de energia solar.

ROOT DEVELOPMENT OF THE SUGARCANE CULTIVARS H32-8560 AND H57-5174, UNDER NORMAL CONDITIONS OF CULTIVATION AND IRRIGATION IN THE CHICAMA VALLEY

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ABSTRACT

A study dealing with the distribution of roots in the soil profile was made in representative and commercially grown fields of the Casa Grande Cooperative. Samples were made in both plant canes and ratoons from 4 to 19 months of age.

The results show that roots grow down to 180 cm depth, with approximately 85% of them within the first 60 cm. Root development is influenced by irrigation. High volumes cause a deeper root development, otherwise, light applications induce a superficial one.

Moreover, under the experimental conditions, it has been found that the age is not an additional factor in the distribution of roots, nor the cultivar or number of harvests.

INTRODUCTION

Sugarcane roots are responsible for the fixation and absorption of nutrients and water that the plant needs for its own growth. The physical and mechanical characteristics of soil which are inappropriate for its normal development, have negative effects on the growth and development of the plant. Some effects are indirect through their influence on the moisture, aeration and nutrients supply, whereas others, such as the mechanical resistance offered by a hard layer against penetration of roots, directly performs negative influences on the growth and distribution of roots. Compaction is a natural fact that can be accelerated as a consequence of the mechanized operations and with different results, depending mainly on the soil structural stability and its moisture degree. Additional ecologic factors, such as the high water tables, alter the normal development of roots influencing their depth and distribution.

Many researchers relate the soil physical characteristics to root development by means of the texture values or bulk density. Veihmeyer and Hendrickson[1] indicate that roots do not penetrate in soils with bulk densities greater than 1.9 g/cm^3, for clayey soils the critical values are still lower. For sugarcane Baver as cited by Gomez and Pinto[2], reports growth restrictions in the root system by presence of hard soil layers. Trouse and Humbert[3] indicate that the growing rates of roots vary

with the bulk density, and that at bulk densities greater than 1.46 g/cm^3, the penetration is heavily reduced, and in soils with values over 1.52 the penetration is null. The same authors did not find differences in root development for critical values of bulk density at different moisture levels.

Gomez, and Pinto[2] in cane-growing soils found bulk density values from 1.7 to 1.8 g/cm^3 in poor growing areas. Botta and Volf[4] on studying the morphology of the root system in the cultivars B-4362 and C-8757, under crop normal conditions in Cuba, determined that more than 70% of roots are found within the first 30 cm depth, about the 20% within the following 30 cm depth, and the remaining percentage below the 60 cm depth, reaching depths down to 180 cm. Neumnan[5] mentions that the roots are found in a great proportion in the first 60 cm in appropriate conditions of soil and moisture where they penetrate very deeply, reaching 120 cm or more. For scheduling irrigation for sugarcane in Mexico, Gonzalez and Ortiz[6] indicated that sugarcane develops about the 90% of its roots in the first 60 cm depth, with the 60% in the first 30 cm. Baran *et al*[7] report that root development at the lower soil horizons was greater when the crop was less frequently irrigated.

For soils with water tables below 80 cm depth, bulk densities of 1.38 to 1.56 g/cm^3, and salinity levels of less than 7 mmhos/cm, Barreto[8] found that approximately the 60% of roots develop in the first 30 cm, with the 80% in the first 60 cm, and almost 95% down to 90 cm depth.

Eppink and Bazan[9] on studying the effects of static water tables on root development of cultivar H32-8560, found that the water table position determines its roots distribution which show a dynamic variation through the profile adapting themselves to the conditions usually present in the soil. The same authors annotate that when the plant is in unfavorable moisture conditions, the root system develops in such a way that great part of the roots are found below the 60 cm. In normal conditions, approximately 70% of roots are found in the first 70 cm, about the 90% down to 90 cm, and almost 100% within the 120 cm depth.

MATERIALS AND METHODS

The study was carried out in eleven representative fields of the Cooperativa Agraria de Produccion (CAP) Casa Grande, nine of which were cultivated with H32-8560 and two with H57-5174. Four pits per field were dug for samplings, the same that were taken at layers of 30 cm down to the depth of 180 cm, using the dry sifting method for the evaluation of samples, (Eppink and Bazan[9]). The selected fields have loam to silty loam texture ($40 < K_A$* 65), low salinity ($0.76 < CE_e$** < 1.87), and average bulk density in the first 90 cm of 1.32 to 1.46 g/cm^3. At sampling time, two of the fields were with plant cane, four were with first ratoon, three with second, one with third and one with fourth. Their ages are as follows: one field, five months: five, between six and twelve months; and the remaining five, of more than twelve months.

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* *K_A, moisture percentage of saturated paste.*

** *EC_e, electrical conductivity of saturation extract in mmhos/cm.*

The characteristics of the irrigation applied to each field were recorded, taking down the applied volume per irrigation, number and interval of irrigations.

The probability density curve of the percentage of roots per layers and a graphic correlation between the mean volume applied per irrigation and the average percentage of roots per layers were established. Correlations (multiple) between the % roots per layers, with the age, number of crop, cultivar, and the respective variance analyses were also made with the purpose of determining the influence of these factors on the development and distribution of roots.

RESULTS AND DISCUSSION

The results are summarized in Table 1, where the roots distribution per field and per layer of 30 cm each as well as the physical characteristics of saturation percentage (K_A), bulk density (DA) soil salinity (CE_e), cultivar, number of crop, age at date of sampling, and irrigation regime applied to each field are shown.

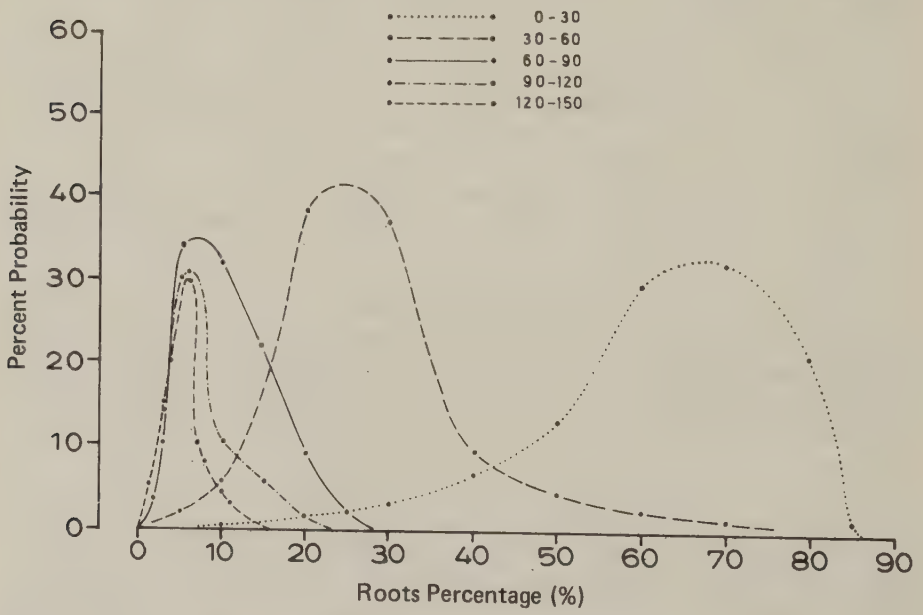

FIGURE 1. Probability density of sugarcane roots percentage (%) per 30 cm of soil depth.

The percentage of roots distribution per layer is represented in Fig. 1 by means of the probability density curve; where it can be observed that around 60% of roots is distributed within the first 30 cm, about 85% within the first 60 cm, and approximately the 94% within the first 90 cm depth. The negative skewness in the 00-30 cm curve, indicates that values less than the 40% are somewhat frequent. Likewise, the skewness of the 30-60 cm curve also indicates the usual lesser frequency that percentages greater than the 40% have within this layer. The values of the

coefficient of variability that are shown in Table 1 also indicate that root distribution below the 60 cm is more variable than in the underlying layers; being less variable in the first one. This type of distribution is the same with that described by Neumnan[5], Barreto[8], Eppink and Bazan[9], Gonzales and Ortiz[6], but somewhat different to that found by Botta and Volf[4], mainly at the root distribution within the layers of 00-30 cm (70%) and 30-60 (20%) probably because the root distribution pattern is determined, in this cases, by different ecology and grown cultivars.

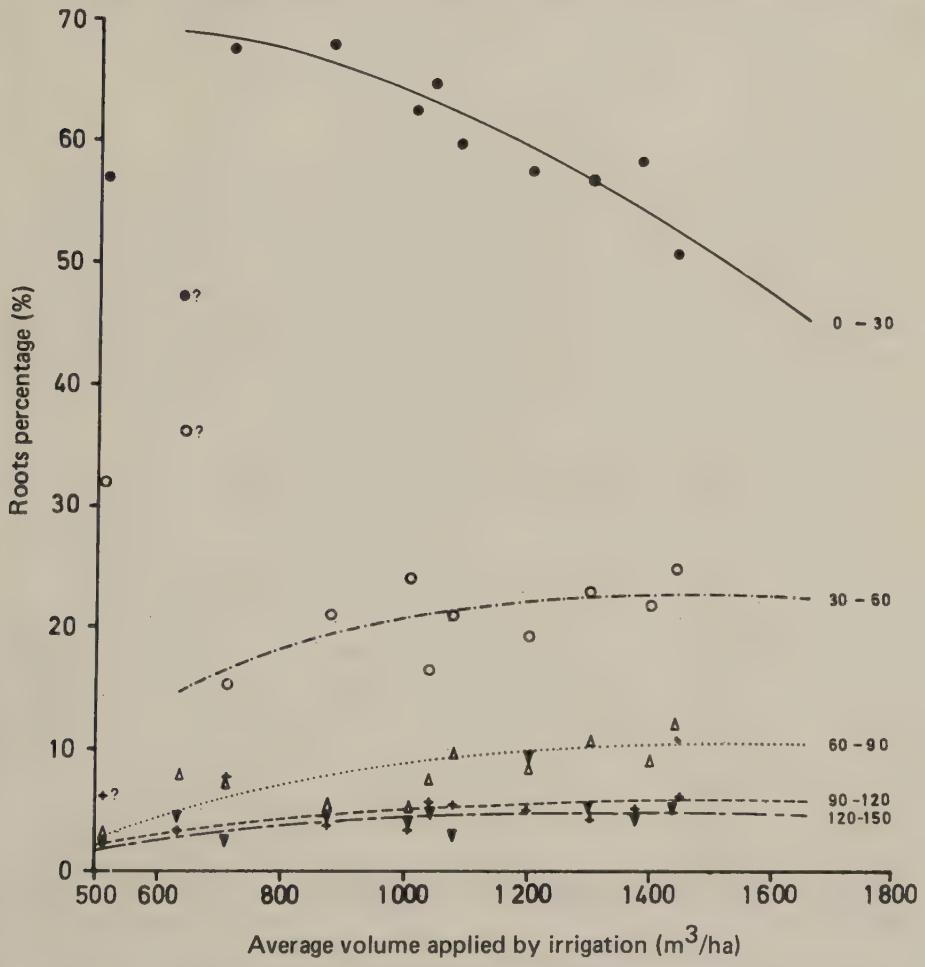

FIGURE 2. Roots distribution as a function of the average volume applied by irrigation.

Fig. 2 reveals that the form of root distribution with depth is related to the irrigation regime; thus abundant applications of water by irrigations with extended intervals between them, caused greater root development at the lower layers. Otherwise, light applications by frequent irrigation generated a superficial development. Baran *et al*[7], Neumnan[5], Eppink and Bazan[9] also indicated that root development is related to both the irrigation regime and the moisture in the profile.

TABLE 1. Summary of soil characteristics per field, irrigation regime, cultivar, age, harvest and distribution of roots.

Field	Cultivar	Harvest	Age at sampling days	Irrigation regime: No. of Irrigations at sampling	Irrigation regime: Average Interval interval days	Irrigation regime: Mean Volume per irrigation m^3/ha	Irrigation regime: Total Volume at date of sampling m^3	Soils: K_A [1]	Soils: CE_e [2]	Soils: DA [3]	% roots per layers of 30 cm.: 00-30	30-60	60-90	90-120	120-150	150-180
Estancia	H32-8560	1°	566	13	44	632	8220	42.1	1.70	1.46	47.6	36.10	7.82	3.64	1.94	2.90
Guayaquil	H32-8560	1°	580	12	48	713	8550	55.1	1.87	1.38	67.4	15.6	7.13	7.33	2.54	– –
Sol II	H32-8560	2°	439	8	55	1298	10385	55.0	0.76	1.38	57.0	22.8	10.50	4.50	5.20	– –
Albertini	H32-8560	2°	395	11	36	1037	11410	44.3	1.05	1.45	64.7	16.5	7.52	5.62	3.46	2.20
Pampes I	H57-5174	planta	275	13	21	510	6630	65.7	1.02	1.32	56.5	31.8	3.14	6.35	2.21	– –
Chacarilla	H32-8560	1°	358	9	40	1076	9686	44.6	1.14	1.44	60.3	21.3	9.84	5.41	3.15	– –
Palmillo 2	H32-8560	2°	193	5	39	1195	5974	49.6	1.25	1.41	57.8	19.5	8.40	4.98	7.33	2.00
Roma	H57-5174	planta	336	14	24	1006	14097	54.7	1.41	1.38	63.0	24.3	4.90	3.53	3.73	0.55
Lache Tanque	H32-8560	3°	215	3	72	1439	4317	58.3	0.78	1.36	51.2	25.0	12.20	6.17	1.56	3.87
Chuin	H32-8560	4°	120	2	61	1379	2759	40.3	0.99	1.47	58.6	22.3	9.13	5.39	4.58	– –
Pucuche B	H32-8560	1°	289	5	58	875	4377	48.7	1.69	1.42	67.7	21.3	5.57	3.95	1.48	– –
SUMMARY																
Average ($\bar{x}$)				9	45	1014	7855	50.1	1.22	1.41	60.4	22.6	7.90	5.50	3.50	0.78
Standard deviation (S)				4	16	307	34.30	7.8	0.38	0.05	14.2	11.50	5.10	4.80	3.50	2.10
Coefficient of variability (CV)											0.24	0.51	0.65	0.87	1.01	2.70
Modal (MO)											63.1	22.7	8.84	9.54	2.46	1.39

Moisture percentage of saturated paste.

Electrical conductivity of soil saturation extract in mmhos/cm

Bulk density in g/cm^3.

Bulk density values of sampled fields are below those considered by the international literature as critical for normal root development (Veihmeyer and Hendrickson[1], Trouse and Humbert[3], Gomez and Pinto[2], and others). The textural characteristics and salinity values were not also limiting for root development and only in limited cases some profiles showed a coarse texture and stones within the lower layers.

Under the experimental conditions, the established correlation between the percentage of root per layer and age, does not show levels of casual association ($r = 0.36$); either with the cultivars or with the crops.

CONCLUSIONS

In the Peruvian coastal north, the sugarcane crop develops its roots down to the depth of 1.80 m, with 85% being frequently found in the first 60 cm of profile, from which the 60% is generally found in the first 30 cm.

For the ecologic conditions and irrigation regime used in the sugarcane crop in the north coast of Peru the root development is influenced by irrigation. Abundant applications of water with extended irrigation intervals induce a deeper root development; whereas, light and frequent irrigation causes a superficial one.

The distribution of roots within the first layers (00-30 and 30-60) shows less variations than those in the deeper layers. The characteristics of the probability density curve in the first two layers indicate that generally more than two-third (2/3) of the roots are distributed in the first 60 cm depth.

Due to the discreet value of the coefficient of correlation between the distribution by layers and age at sampling, it is inferred that this has not been an additional factor in the form of distribution of roots at the profile, and/or that at the age of sampling (age $>$ 4 months) the roots profile apparently has a complete development. Likewise, bulk density values and salinity levels have not been restrictive for root development. The number of harvests and the cultivar did not influence root development.

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DESARROLLO RADICULAR DE CULTIVARES DE CAÑA DE AZUCAR H32-8560 y H57-5174, BAJO CONDICIONES NORMALES DE CULTIVO Y RIEGO EN EL VALLE CHICAMA

J. E. Paz-Vergara, A. Vasquez, W. Iglesias and J. C. Sevilla

RESUMEN

Fue hecho un estudio para apreciar la distribucion de las raices en el perfil del suelo de campos comerciales de caña de azucar en la Cooperativa Casa Grande. Las muestras fueron tomadas tanto en caña planta como seca de 4 a 19 meses de edad.

Los resultados demuestran que las raices crecen hasta 180 cm. en profundidad, estando aproximadamente el 85% de ellas en los primeros 60 cm.

El desarrollo radicular esta influenciado por la irrigacion. Altos volumenes de agua causan un desarrollo radicular profundo, mientras que por otro lado, aplicaciones ligeras inducen a raices superficiales.

Asi mismo, bajo condiciones experimentales se ha encontrado que la edad no es un factor adicional causante de la distribucion radicular, ya sea en el cultivar o en el numero de cosechas.

GROWTH, YIELD AND JUICE QUALITY PERFORMANCE OF SUGARCANE VARIETIES UNDER DIFFERENT SOIL MOISTURE REGIMES IN RELATION TO DROUGHT RESISTANCE

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ABSTRACT

Field experiments were carried out in 1974-75 at the research farm of the Sugarcane Breeding Institute in Coimbatore, India to study the growth, yield and juice quality performance of sugarcane varieties under 60, 40 and 20% avaliable soil moisture maintained during the formative stage of the crops in relation to their drought resistance. Growth, cane yield and juice quality were affected most adversely when available soil moisture decreased from 60 to 20 followed by 40 to 20 than that of 60 to 40%. The rate of leaf emergence was least affected, while growth in height followed by leaf area were most sensitive to moisture stress. The magnitude of effect differed with the varieties. In all the moisture regimes, especially under lower soil moisture, varieties with thin stalks and shorter mother shoot have more green leaves, leaf area, tillers and rate of leaf emergence as compared to varieties with thick stalks and tall mother shoot.

The deleterious effect of moisture stress on juice quality was higher during the early (10 months age) than that of the late period (12 months age) of maturity phase. Under lower soil moisture, there was a trend of progressively greater reduction in sucrose % juice and increased reducing sugars with increasing maturity lateness and stalk thickness of a variety. Depression in cane yield and commercial cane sugars and also in juice quality characters from 60 to 20% available soil moisture was more in less drought resistant varieties Co 419 Co 527, Co 658, Co 740 and Co 1158 than inCo 1148, Cos 510, Co 853 and Co 997. Thin-stalked varieties, in general, appeared to resist drought better than those with thick-stalked ones. The physiological basis for deterioration in juice quality under lower soil moisture at Coimbatore has been discussed.

INTRODUCTION

To assess the effect of dry environment on yield and also before genetic aspects of drought resistance can be studied, an understanding is needed of plant

growth, juice quality and yield components, (tonnage and Commercial Cane Sugar per hectare) responses to moisture stress in a large number of varieties. Lal and Mehrotra[18] consider a sugarcane variety to be physiologically more resistant than others if it posesses larger number of shoots per plant, greater green leaf number and extensive root system. Similarly, Singh and Remakrishnan[27] reported that varieties with thin stalks produced more leaves and tillers and shorter mother shoots than varieties with thick stalks at early stages of growth. The former, which mainained higher green leaf number suffered less than the latter under moisture stress.

Sugarcane plants formative growth stage suffer most from drought in many parts of India because of the summer months so that knowledge of the optimum soil moisture is necessary. This knowledge would help in regulating irrigation in commercial crops for better yields. It would also avoid the possibility of rejecting some promising genotypes which may not be able to express the heritable values from the parents especially sucrose % juice and Commercial Cane Sugar due to moisture stress. Barber[4] reported that at this Institute farm, wetland seedlings gave higher sucrose % juice than those planted in garden land soil. These findings were subsequently confirmed in hybrid varieties experimented by Dutt and Iyer[9] and Krishnamurthy and Iyer[15].

In sub-tropical India, results on the effects on juice quality of moisture stress imposed during early grwoth stages are conflicting. Raheja[24] reported that Commercial Cane Sugar % was higher under the critical soil moisture limit than under normal irrigation. Similarly at Shahjahanpur, soil moisture stress at early stages of growth slightly improved the juice quality (Anon[2]). Results on juice quality of the sugarcane crop subjected to moisture stress during formative growth stage reported by a number of workers (Gahlot[12], Singh and Singh[26], Verma Singh[31]) do not, however, support this contention, but on the contrary, tended to show a depression in juice quality.

Investigations made by a number of workers (Basu and Thakur[5], Baver[6] Cheema and Moblani[7], Clements[8], Lakshmikantham and Rao[17], Malik and Venkataraman[20], and Mongelard[22]) showed that moisture variation adversely affected the growth and yield of sugarcane. According to most of these workers, for economic and optimum crop production, the optimum requirement of soil moisture at active root zone is 50% depletion of the available soil moisture which may slightly vary depending on soil fertility, variety, climate and growth conditions. However, information on responses of the different sugarcane varieties to moisture stress with respect to their stalk thickness and early and late maturity characters both in relation to cane yield and juice quality is limited especially in tropical regions, Also, most of the earlier studies conducted on moisture requirements of sugarcane are restricted with a single variety.

With this end in view, field experiments were carried out to investigate the behaviour of certain drought resistant, medium resistant and susceptible varieties with varying stalk thickness and also in their earliness and lateness of maturity under different soil moisture regimes with reference to their early growth characters, tonnage and juice quality under Coimbatore conditions.

MATERIALS AND METHODS

In 1974-75, nine commercial sugarcane varieties CoS 510, Co 997, Co658 (early maturing) and Co 527, Co 740, Co 1158, Co 853, Co 1148, Co 419 (mid and late maturing) were planted during the first week of February in split plot design with soil moisture treatments as main plots and varieties as sub-plots at the research farm of this Institute. There were 24 sets per row of 6.1 meter length. Varieties Co 419, Co 740, Co 658 and Co 527 were thick-stalked ranging from 2.6 to 3.0 cms in stalk diam. Thin-stalked varieties included CoS 510, Co 1158, Co 1148, Co 997, Co 853 with a range of 2.0 to 2.5 cms in stalk diameter. Plot size was 28.1 sq m replicated four times. The normal rates of N, P and K were applied at 225 kg, 75 kg and 75 kg and 75 kg per ha at the time of planting. The moisture treatments were 60, 40 and 20% available soil moisture maintained at 22-44 cm depth by irrigation. The field capacity of the soil was 22% with permanent wilting percentage of 9%.

Field capacity was determined following the method described by Piper[23] and permanent wilting percentage was measured by sunflower wilting technique (Marshall and Williams[21]). Irrigation interval corresponding to 60, 40 and 20% available soil moisture was nearly 6-8, 10-12 and 20-25 days. Differential moisture treatments started on March 19, 1974 and terminated on July 10, 1974. During the period of moisture treatment application, there were 30.6, 76. and 2.6 mm. rainfall during April, May and June, respectively.

Observations on early growth characters included mother shoot height, mother shoot green leaf number, rate of new leaf emergence, tiller number and leaf areas per plant which were recorded fortnightly from 20 plants (4 plants from each cane row) for each variety distributed at random in each plot. The leaf area was calculated by the method suggested by Lal and Subba Rao[19]. To adjudge the significance of the effects of soil moisture regimes on plant performance and on the relative varietal traits, the analysis of variance was computed of the data on these early growth characters which were recorded at 70, 100 and 130 days after planting.

On the basis of stalk thickness, the varieties were classified into thick and thin stalk groups and the mean values of these early growth attributes at a group level obtained at 60 and 20% available soil moisture. Correlation coefficient was determined between the early growth attributes and the ultimate yield of the varieties under 60 and 20% available soil moisture.

Juice analyses were made in the months of December and February (at harvest). Twenty sugarcane stalk samples were used for juice anlysis. In each plot, four cane stalks were selected at random from each cane row (i.e. 4 canes x 5 rows). The juice samples were analyzed for 'brix' and pol (sucrose) using the Standard Brix hydrometer and the Schmidt and Haensch Polarimeter, respectively, according to the method adopted by Sugar Technologists' Association of India[1]. Reducing sugars in juice were also estimated following the method of Vander plank[29]. Harvesting was done during the end of February and beginning of March and observations on cane yield and millable cane number were recorded.

RESULTS

Germination

The treatment differences were not significant because the differential moisture treatments commenced only after germination was over. The maximum germination of 71.1% was obtained from in Co 740 and the minimum of 38.2% from C 658.

Mother shoot height

Data collected indicated that mother shoot height decreased at all the stages, with increasing soil moisture stress. The treatment differences were significant at all stages except at 70 days where there was no difference between 60 and 40%. Marginal means for variety showed that at all three stages, varietal differences were significant and thick stalked varieties were taller than the varieties with thinner stalks. With decreasing available soil moisture from 60 t0 20%, the height decreased in all the varieties at all the stages with the maximum adverse effect noted at 20% available soil moisture. The interaction between varieties and moisture regimes was significant both at 70 and 100 days.

Leaf number

The marginal means for moisture treatment for green leaf number indicated that treatment differences were significant at 70 as well as at 150 days. The depressing effect of moisure stress was greater under 20% soil moisture. Marginal means for variety indicated that at all stages, thick-stalked varieties Co 419 and Co 658 had lower leaf number as compared to relatively thin-stalked varieties Co 1148, Co 853 and Co 1158. At initial stages, variety C '740 produced leaves at a faster rate but decreased subsequently and was surpassed by other varieties At almost all stages of growth, with the increasing moisture stress, green leaf number decreased in all the varieties especially in C 419. The interaction between variety and moisture treatment was however not signiifcant.

Leaf area

The marginal means for moisture treatment for leaf area per plant indicated that at 70 days although leaf area decreased at 20% available soil moisture, the difference was not significant. At 100 days, the treatment difference between 60 and 40% and that between 60 and 20% was significant. However, there was no significance between 40 and 20%. At 130 days, leaf area decreased significantly with increasing moisture stress. Marginal means for variety showed that they differed significantly only at 70 and 100 days.

Leaf emergence

The marginal means for moisture treatment for the rate of leaf emergence indicated that treatment differences were significant only at the age of 130 days

and only between 60 and 20% available soil moisture. This implies that leaf emergence was least sensitive to soil moisture stress. Marginal means for variety indicated that varietal differences were significant only at the later two stages. Significant interaction between moisture regimes and varieties at 230 days are suggested that soil moisture variation caused varied effects on the nine varieties especially at 60 to 20% available soil moisture. The decrease was greater in thick stalked than in thin stalked varieties.

Tiller number

The marginal means for moisture treatment for tiller number per plant indicated that a decrease with increased moisture stress and the differences were significant at 70 and 130 days. There were differences between 40 and 20% whereas at 130 days age, the difference between 60 and 20 and that of 40 and 20% were significant. There was no significant difference in tiller number at 60 and 40% available soil moisture. Marginal means for varieties showed that at all three dates differences in tiller number were significant.

Thin-stalked varieties produced more tiller as compared to thick-stalked ones. Initially, Co 740 produced tiller at a faster rate but progressive decrease in the rate was noted when compared with other varieties. The interaction between variety and moisture treatment was significant only at 130 days. It was found out that a decrease in available soil moisture from 60 to 40% reduced tiller number significantly only in some of the varieties.

Athough the effects of soil moisture variation was observed on the different early growth stages, it was more noticeable at the later stages when plants were displaying faster growth. Again, a progressive decrease in these early growth characters was often not consistent between 60 and 40% and between 40 and 20% although plants under 20% showed large and consistent inhibition especially when compared with 60% available soil moisture.

Early growth attributes of thin and thick stalked group

As shown in Table 1, early growth attributes such as green leaf production, rate of leaf emergence, leaf area and tiller number per plant were higher in thin-stalked than in thick-stalked at all growth stages, both under 60 and 20% available soil moisture. However, differences between the two groups were more apparent under high moisture stress. Mother shoot was greater in thicker than thinner stalked varieties especially under 60% available soil moisture although similar to other growth attributes, reduction in height under 20% available soil moisture was greater in the former than in the latter group.

Yield

Cane yield (Table 2) decreased significantly at 60 or 40 to 20% available soil moisture but there was no significant difference between 60 and 40%. In all the varieties, cane yield decreased with increasing soil moisture stress. The magnitude of effect differed with increased soil moisture stress. The magnitude of

TABLE 1. Comparison of early growth attributes of two groups of varieties under two soil moisture conditions

Growth Attributes	Age (days)					
	70		100		130	
	G1*	G2*	G1*	G2**	G1*	G2**
1. Optimum soil moisture						
No. of green leaves/ mother shoot	5.06	5.30	6.36	7.00	7.23	7.76
Leaf area in sq cm/ plant	307.8	319.7	1281.3	1406.0	3416.1	3957.1
No. of tillers/plant	2.30	2.40	3.20	3.86	3.00	4.60
Fortnightly rate of leaf emergence/ mother shoot	3.23	3.60	1.45	1.52	1.75	1.84
Average mother shoot length in cm	19.82	17.14	38.41	30.81	60.60	56.39
2. Soil moisture stress						
No. of green leaves/ mother shoot	4.20	4.26	6.10	6.40	5.56	5.83
Leaf area in sq cm/ plant	217.7	739.4	659.1	688.1	1060.1	1237.2
No. of tillers/plant	1.70	1.26	2.26	2.50	2.26	2.66
Fortnightly rate of leaf emergence/ mother shoot	2.45	2.56	1.07	1.33	0.47	0.66
Average mother shoot length in cm	14.36	14.29	21.47	19.82	28.56	23.68

G1 = Thick stalked variety, average stalk diameter = 2.8 cm*
*G2** = Thin stalked variety, average stalk diameter = 2.4 cm*

effect differed with the varieties being less in Co 1148 CoS 510, Co 853 and Co 997 as compared to Co 419, Co 527, Co 658, Co 740 and Co 1158. The interaction between moisture regimes and varieties was however not significant. Millable cane number followed the same trend as in cane yield. Thin stalked variety in general had greater number of millable canes/ha than that of thick stalked varieties. It was also noted that under moisture stress, there was a tendency of decreasing cane yield with their increasing stalk thickness of varieties.

Juice quality

Results on juice quality were obtained in December (10 months age) and February (12 months age) (Table 3). Juice quality decreased with reduced soil moisture. The differences between moisture regimes for sucrose % juice and Com-

mercial Cane Sugar per cent both for December and February were significant but for purity it was significant only in February. For Brix in December, all the differences between the treatments were significant except between 60 and 40% while in February, it was significant only between 60 and 20%.

Marginal means for moisture regimes for reducing sugars in juice indicated that it increased significantly with decreasing moisture regimes and all the differences between the moisture regimes were significant. In both December and February, varietal differences for all the quality characters were significant. The magnitude of moisture effects differed among varieties but was relatively higher in thick-stalked plants. There was also a trend of progressively greater reduction in sucrose % juice and increased reducing sugars in juice with increasing maturity lateness of a variety. Unlike early growth attributes and cane yield, all differences between the treatments for almost all juice quality characters were statistically significant indicating greater adverse effect of soil moisture on juice quality.

TABLE 2. Yield and Commercial Cane Sugar Performance of Sugarcane Varieties Under Different Soil Moisture Regimes

Varieties	Sugarcane Yield (Tons/ha) Available Soil Moisture (%)				Commercial Cane Sugar (Tons/ha) Available Soil Moisture (%)			
	60	40	20	Mean	60	40	20	Mean
Co 419	114.70	97.31	91.44	101.15	13.20	10.70	8.82	10.91
Co 527	68.43	64.68	55.93	63.02	8.95	7.13	5.69	6.97
Co 1158	66.74	59.78	49.94	58.82	7.32	6.34	4.97	6.18
Co 740	124.13	116.59	92.13	110.95	15.98	14.01	10.35	13.45
Co 658	76.65	71.91	48.91	65.82	9.65	8.74	5.59	7.99
Cos 510	84.34	80.53	71.47	78.78	8.85	8.54	7.50	8.79
Co 853	81.51	83.00	71.13	78.55	9.87	9.78	7.25	9.97
Co 1148	78.36	69.11	71.68	73.05	8.95	7.61	7.28	7.95
Co 997	82.35	82.02	67.55	77.31	10.31	10.04	8.00	9.45
Mean	86.36	80.55	68.91		10.25	9.20	7.27	

		Sugarcane Yield (Tons/ha)	Commercial Cane Sugar (Tons/ha)
Treatments	SE D	3.99	0.48
	LS D	9.76	1.174
Varieties	SE D	3.79	0.45
	LS D	7.43	0.88
Interraction		MS	Sig
1. To compare two means of the treatment against a variety		SED	0.72
		LSD	1.50
2. To compare two means of the variety against a treatment		SED	0.79
		LSD	1.35

TABLE 3. Juice Quality Performance of Sugarcane Variety Per Different Soil Moisture Regimes

Variety	Sucrose (% juice)				Reducing sugars in juice (%)				Commercial cane sugar (%)			
	60	40	20	MEAN	60	40	20	MEAN	60	40	20	MEAN
Co419	16.74 (14.55)	16.12 (12.34)	14.28 (10.68)	15.71 (12.52)	(1.801)	(2.253)	(2.182)	(2.079)	11.47 (9.75)	11.04 (7.95)	9.63 (6.88)	10.71 (8.16)
Co 527	17.19 (15.07)	16.17 (12.59)	15.02 (11.38)	16.13 (13.01)	(1.503)	(1.748)	(1.945)	(1.732)	11.83 (10.20)	11.02 (8.14)	10.17 (7.36)	11.00 (8.56)
Co 1158	16.36 (16.54)	15.59 (14.85)	15.03 (11.23)	15.66 (14.21)	(0.765)	(0.918)	(1.443)	(1.042)	(10.98) (11.03)	10.36 (9.84)	9.98 (6.72)	10.44 (9.19)
Co 740	18.44 (16.12)	17.39 (13.62)	16.40 (22.46)	17.41 (13.73)	(0.923	(1.362)	(1,494)	(1,259)	12.88 (11.11)	12.07 (9.05)	11.23 (7.30)	12.06 (9.15)
Co 658	17.94 (16.42)	17.37 (14.28)	16.40 (12.27)	17.25 (14.32)	(0.886)	(1.062)	(1.582)	(1.176)	12.59 (11.40)	12.02 (9.46)	11.29 (8.07)	11.96 (9.64)
Cos 510	15.63 (13.69)	15.69 (13.04)	15.53 (11.73)	15.62 (12.82)	(1.312)	(1.454)	(1.759)	(1.508)	10.51 (8.63)	10.59 (7.55)	10.53 (8.37)	10.54 (8.37)
Co 853	18.24 (16.09)	16.62 (15.62)	15.53 (12.62)	16.73 (14.78)	(0.904)	(1.208)	(1.896)	(1.336)	12.13 (10.73)	11.32 (10.52)	10.23 (8.25)	11.22 (9.83)
Co 1148	16.91 (16.26)	16.27 (14.13)	15.22 (12.88)	16.14 (14.42)	(1,345)	(1,415)	(1.926)	(1,562)	11.41 (11.10)	11.03 (9.42)	10.16 (9.36)	10.86 (9.96)
Co 997	18.11 (14.62)	17.53 (13.31)	17.13 (12.61)	17.59 (13.61)	(1.517)	(1.608)	(1.926)	(1.684)	12.55 (9.93)	12.04 (8.76)	11.82 (8.50)	12.13 (9.06)
Mean	17.29 (15.48)	16.52 (13.75)	15.59 (11.90)		(1.217)	(1.447)	(1.795)		11.81 (10.46)	11.27 (9.08)	10.56 (7.78)	

		Sucrose (% Juice)	Reducing Sugars in Juice (%)	Commercial Cane Sugar (%)
Treatment	SED	0.125 (0.195)	(0.078) (0.216)	0.110 (0.56)
	LSD	0.305 (0.477)	(0.216)	0.273 (1.370)
Varieties	SED	0.313 (0.448)	(0.079)	0.850 (0.45)
	LSD	0.613 (0.878)	(0.155) (NS)	1.666 (0.88) NS (NS)
Interaction		NS (Sig.)		

1) To compare two means of the SED (0.650)
treatments against a variety LSD (1.404)
2) To compare two means of SED (0.774)
the varieties against a treatment LSD (1.517)

Figures in Parenthesis and without parenthesis were recorded in December (10 months age) and in February (12 months age) respectively.

sucrose % juice and increased reducing sugars in juice with increasing maturity lateness of a variety. Unlike early growth attributes and cane yield, all differences between the treatments for almost all juice quality characters were statistically significant indicating greater adverse effect of soil moisture on juice quality.

Correlation between early growth attributes and cane yield

At early growth stages mother shoot height was more significantly and positively correlated with cane yield under both moisture stress and irrigated conditions and 'r' value increased with age of the crop (Table 4). Varieties with thick stalks tended to show stronger correlation than varieties with their stalks. Leaf number per mother shoot and tiller number per plant were positively associated with cane yield which was higher under stress of drought than under optimum soil moisture. Under moisture stress, association of leaf area with cane yield was posi-

TABLE 4. Coefficient of correlation between early growth characters and cane yield

Age in days	Early growth characters	Available soil moisture per cent					
		60			20		
		At a group level			At a group level		
			G1	G2		G1	G2
55	Height (mother shoot)	+0.647	+0.850	+0.439	+0.630	+0.965*	+0.209
70		+0.629	+0.0999**	+0.320	+0.639	+0.978*	−0.148
35		+0.779*	+0.985*	+0.391	+0.717*	+0.990*	+0.074
100		+0.821*	+0.990*	+0.280	+0.711*	+0.980*	**+0.370**
130		+0.803**	+0.990*	−0.005	+0.800**	0.983*	+0.510
70	No. of tiller per plant	+0.250			+0.540		
100		+0.048			+0.689*		
130		+0.580			+0.509		
70	No. of leaf per mother shoot	+0.203			+0.541		
100		+0.288			+o.558		
130		+0.276			+0.588		
70	Leaf areas (Sq cm) per plant	+0.270			+0.820**		
100		+0.026			+0.772**		
130		−0.469			+0.369		
160		−0.641			+0.352		

** Significant at 5% level*
*** Significant at 1% level*

G1 thick stalked variety, ave. diam. 2-8 cm
G2 thin stalked variety, ave. diam. 2-4 cm

tive. and significant which became weaker with age, while under optimum soil moisture, it was negative which became stronger with age.

DISCUSSION

The results indicate that the depressing effects on different early vegetative growth characters between 60 and 40 and between 40 and 20% available soil moisture were of different magnitudes which varied both with attributes and stages. However, in general, growth suffered more in the later than in the former. The impact of moisture stress on growth in mother shoot height, rate of new leaf emergence and leaf area per plant was relatively less during early stages except in the plants under 20% available soil moisture which showed marked inhibition from the initial stages. But after about 100 days when plants displayed faster growth, moisture variations brought about the expected differences possibly because of greater integrated impact of moisture stress as well as greater demand of water at later stages of growth.

With regards to sensitivity of individual growth attributes to moisture stress it was found out that the rate of leaf emergence was least affected while height followed by leaf area was most sensitive to moisture stress. Fischer and Hagen[11] have stated that in other crops leaf initiation was almost insensitive while leaf area was most sensitive to moisture stress. There was significant interaction between moisture regimes and varieties especially at later stages for mother shoot height, tiller number and leaf emergence which indicated that soil moisture variation had an effect in the nine varieties at varying magnitude.

At all the growth stages, both under higher and lower soil moisture, varieties with thin stalks and shorter mother shoot namely: CoS 510 Co 997 and Co 1158 have more leaves, leaf area, tillers and rate of leaf emergence as compared to thick-stalked varieties such as C 419. Co 658 and Co 740 in the early stages of crop growth (Table 1). Gill and Singh[13] observed that drought resistant variety Co 312 maintained a higher percentage of green leaves under the controlled irrigation experiment. Lal and Mehrotra[18] also reported that a drought resistant variety generally possessed higher green leaf number and larger shoot number per plant. Again higher positive association of leaf number, tiller number and leaf area recorded at early growth stages with cane yield under stress of drought as compared to normal irrigation conditions (Table 4) indicated that varieties with more leaves, tillers and leaf area under stress would resist drought better than plants with less leaf number, tiller and leaf area. Rate of leaf senescence under stress was minimum in a drought resistant variety Co 997 while it was maximum in a susceptible variety Co 419. Fischer and Hagen[11] indicated that the sensitivity of dry matter yield to stress should be greater in a crop grown with a low leaf area index than in a crop with a high leaf area index. Under moisture stress, the girth of cane showed a negative association with cane yield and this was significant indicating that varieties with thin stalks would do well under water stress Anon3. If therefore seems that plants with initial vigour in terms of tiller number, leaf number and leaf area would avoid drought better than normal or weak plants. Lahiri *et al*[16] in Pennisetum typhoides found that plants with optimum vigour induced by

adequate level of nitrogen were able to evade the adverse effects of drought more than normal plants.

More or less, similar to early growth characters, reduction in cane yield, commercial cane sugar and juice quality characters was higher when available soil moisture decreased from 60 to 20 followed by 40 to 20 than that of 60 to 40 %. However, there was slight variation in magnitude of decrease with respect to yield and quality characters under diffferent moisture regimes. This is shown in Table 3 where all treatment differences for quality characters especially sucrose % juice and commercial cane sugar per cent were significant both in December (10 months age) and in February (12 months age). Similarly, under Commercial cane sugar all the differences except between 60 and 40% were significant (Table 2). The depressing effect of moisture stress on juice quality was more apparent from reducing sugars in juice which increased significantly with decreasing available soil moisture both at 10 and 12 months age. The deleterious effect of moisture stress on juice quality was higher at 10 as compared to 12 months age. Quality characters were found to be more sensitive to moisture stress than cane yield. But both these characters were less affected by water stress than early growth attributes. However, early growth and juice quality characters appeared to have some similarity in their responses to moisture stress. Clements[8] reported that yield does not appear to be as sensitive to water stress as total growth.

In all the varieties, the interaction between moisture level and variety was not significant even if cane yield and juice quality decreased with increasing soil moisture stress. For Commercial Cane Sugar, variety and moisture regime, interaction was significant. Maximum adverse effect of moisture stress was in Co 419 followed by Co 527. Almost all varieties differed significantly with respect to Commercial Cane Sugar between 60 and 10 as well as between 40 and 20 % available soil mositure. Unlike other varieties, Co 419 and Co 527 showed significant reduction in Commercial Cane Sugar even between 60 and 40 % available soil moisture where there was mild stress. Results reported by a number of workers (Basu *et al*[5], Cheema and Moolani[7], Lakshmikantham and Rao[17], Singh and Singh[26]) showed that during early growth stages, reduction of available soil moisture to 50 % at the zone of maximum root concentration, before next irrigation is applied, appeared to be optimum moisture regimes for economic and optimum crop production. Ewart[10] reported to significant cane yield differences whether irrigation was applied at 0.2 0 atm or 2 , 5 , 15 or 50,000 chms. Under Hawaiian condition, there was maximum yield of sugar when the soil was irrigated before 60% of available water had been used at 45 cms depths (Baver[6]).

Depression in main components of yields (both the tonnage and commercial Cane Sugar) and also in juice quality characters from 60 to 20% available soil moisture was more in less drought resistant varieties 9Co 419, Co 527, Co 658 and Co 1158) than in Co 1148, CoS 510 Co 853 and Co 997, known for their field resistance. Depression in cane yield from normal to deficient irrigation as a criteria of drought resistance has been reported by Gahlot[12] and Verma[30]. Stocker[28] also defined drought resistance quantitatively as the ratio of yield under dry conditions to that under optimum conditions of water supply. There was a progressively greater reduction in sucrose % juice and increased reducing sugars with increasing

delay in maturity of a variety when subjected to moisture stress at formative stage. This is evident with late maturing varieties Co 419, Co 1158, Co 1148, and Co 853. It was also observed that under lower available soil moisture, cane yield sucrose % juice, Brix and purity decreased and reducing sugars increased with increasing stalk thickness of the varieties as compared with thicker stalks of varieties Co 419, Co 658 Co 740 and Co 527. This indicates that by and large, thick-stalked and late maturing varieties are more sensitive to moisture stress. Thick-stalked and late maturing varieties which showed greater reduction in cane yield also recorded more deterioration in juice quality both at 10 and 12 months age. This is because they suffered more during early growth stages under soil moisture stress.

It is known that the process of sucrose accumulation is intimately related to the growth process of sugarcane plant. Thus, the more rapid the growth of cane the less rapid is the sucrose accumulation and vice-versa. Dried crops usually grow faster than normal irrigated ones during the period following the termiantion of moisture stress (Clements[8], Robinson[25]) and also take comparatively longer time to complete its growth than normal crop. As a result, dried cane stalks especially during early period of maturity phase, had less sucrose accumulation and higher reducing sugars possibly because of predominance of vacuolar acid invertase in growing immature stalks (Glasziou[14]) under the influence of favourable growth conditions. But with advance in crop age from December to February (10 to 12 months age), the difference in sucrose % juice between 60 and 20, 60 and 40 and 40 and 20% available soil moisture reduced considerably because of greater juice quality improvement in crop subjected to moisture stress (Table 3). Similar results have also been reported by Varma and Singh[31]. The delay in maturity caused by moisture stress appeared to be more in late than in early maturing varieties. This is evident with decreased sucrose % juice under moisture stress more in late than in early maturing varieties. However, both in early and late maturing varieties, sucrose % juice was lower and reducing sugars were higher in dried than in normal crop even at 12 months age. This indicates that under stress conditions for getting maximum sugar yield, harvesting of both early and late maturing varieties should be delayed until they attain their peak maturity. The exact period of harvesting may, however, differ depending on the severity of moisture stress, variety, climate and growth conditions.

From early growth yield and juice quality of varieties such as Co 997, Co 1148, Co S 510 and Co 953 which are known for their drought resistance under field conditions were also found to be less sensitive to moisture stress in the present study. It may also be stated that although both late and early maturing varieties have inherent capacity to tolerate drought, the former showed their superiority over the latter in tolerating moisture stress especially when compared from the point of view of their sugar recovery, than sugar yield per unit area as evident with commercial Cane Sugar per cent (Table 3).

The prolonged growth recovery with decreased sucrose % juice and increased reducing sugars in dried stalks is greater in tropical regions where high humidity and warm climate, conducive for growth, prevail not only during maturity phase but almost all year round. But in sub-tropical regions where low temperature not conducive for growth prevails during maturity phase, results on the effects of

moisture stress on juice quality have been conflicting. Gahlot[12] and Varma and Singh[31] showed that there was a decrease in sucrose % in juice in most of the period of the maturity phase, while results in other places at times indicated that moisture stress at early growth stages improved the juice quality (Anon[7]). Raheja[24] reported similar results. This conflicting result may be because of variation in growth conditions from year to year during the period following the termination of moisture stress, especially during maturity phase.

It seems from the growth, yield and quality performance of varieties under different soil moisture regimes that although optimum soil moisture requirement differs up to a certain extent with the varieties, the available soil moisture between 50 and 60 % at 22-44 cms depths during early growth stages may be considered as optimum for economic tonnage and sugar yield under Coimbatore conditions in garden land soil (sandy-loam).

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CRECIMIENTO, RENDIMIENTO Y CALIDAD DE JUGO DE VARIEDADES DE CAÑA DE AZUCAR BAJO DIFERENTES REGIMENES DE HUMEDAD DE SUELO EN RELACION A SU RESISTENCIA A LA SEQUIA.

Sudama Singh y M. Sanjiva Reddy

RESUMEN

En 1973-74 y 1974-75 se llevaron a cabo experimentos de campo en la finca experimental de este Instituto para estudiar el crecimiento, rendimiento y calidad del jugo de variedades de caña de azucar bajo 60, 40 y 20% de humedad disponible en el suelo mantenida durante el estado formativo de las cosechas en relacion a su resistencia a la sequia. El crecimiento, rendimiento de caña y la calidad de jugo fueron afectado mas adversamente cuando la humedad disponsible en el suelo disminuyó de 60 a 20 seguido por 40 a 20 que de 60 a 40%. Bajo las condiciones de Coimbatore con suelo de huerto (franco arenoso) aparentemente una humedad entre 50 y 60% a profundidades de 22-24 cm, es optima para obtener rendimientos economicos en cuanto a tonelaje y azucar se refiere. La rapidez con que emerge la hoja fue menos afectada, mientras que el crecimiento en altura seguida por area foliar resultaron mas sensitivos a tension de humedad. La magnitud del efecto diferió con las variedades. En todos los regimenes de humedad, especialmente bajo condiciones de baja humedad del suelo, las variedades con tallos finos y tallos maternos mas cortos, tuvieron mas hojas verdes, area foliar, renuevos y una paricion mas rapida de hojas en comparacion con variedades de tallos gruesos y tallos maternos altos.

USE OF GIBBERELLIC ACID TO INCREASE SUGARCANE YIELDS IN HAWAII

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ABSTRACT

A review of growth and yield responses of sugarcane to exogenously applied gibberellic acid (GA_3) is presented. Consistent increases over controls of fresh weight of stalk tissue of plants treated with GA_3 were obtained under the following conditions: (1) treating the best-responding varieties; (2) preferentially treating the higher elevation fields of lowland varieties; (3) timing the GA_3 applications to coincide with winter stunting; (4) allowing sufficient time before harvest for ripening of GA_3-produced growth, and (5) applying GA_3 serially in doses of 1.0 mg or less per stalk at 15-to-30 day intervals.

These conditions were met in field tests in Hawaii where significant gains were made in fresh weight per stalk without a reduction in cane quality. Weight gains were comparable to yield increases of 1.75 metric ton sugar per hectare. Thus, under carefully selected conditions, GA_3 appears to have good potential for use in Hawaii.

INTRODUCTION

Gibberellins were discovered in 1926 by the plant pathologist, Kurosawa, who was working on the bakanae disease of rice (*Oryza sativa*). Early symptoms of this disease include excessive stem elongation, increased lodging, and poor seed set; thus, the name bakanae or "foolish seedling" was coined for the disease. Kurosawa found that media in which the causative organism, *Gibberella fugikuroi* or *Fusarium moniliforme*, had grown would stimulate the growth of rice seedlings even though the seedlings were not infected (Kurosawa[13]). In 1935, Yabuta[25] obtained an active preparation from culture media and named it gibberellin after the fungus from which it was isolated.

Western scientists learned of the Japanese experiments in about 1950 and by 1955 had gibberellins available for experimental and commercial purposes. Within 5 years, many plant species and several physiological processes were found to be affected by gibberellins. The most obvious response to gibberellin applications was

the increase in stem length. Attempts to use gibberellic acid (GA_3) to increase sugarcane yields were first reported in 1956. Since then, a number of conflicting papers have appeared to report the effects of GA_3 on sugarcane and the potential of this hormone for increasing sugar yields. Our recent experiences seem to resolve some of the discrepancies of earlier reports and to indicate a positive potential for use of GA_3 on sugarcane in Hawaii.

In 1956, it was reported that a series of 4 applications of GA_3 caused a 50% increase in stalk fresh weight and a 300% increase in grams pol in young sugarcane stalks (Anon[1]). The total amount of GA_3 used was 80 ug/stalk applied in the whorl of leaves surrounding the spindle leaf. This amount was found not to affect cane growth if the GA_3 was applied as a foliar spray rather than directly to the spindle (Anon[2]).

Field studies established to evaluate the effects of GA_3 on sugarcane yields and reported in 1958 and 1959 failed to show the expected yield increase (Coleman[11], Villareal and Santos[24]). However, indications were given in one of these studies that sugarcane was most responsive to GA_3 when plants were grown under cool weather stress conditions (Coleman[11]).

Subsequent studies reported in 1961 on individual stalk treatments again showed the potential for effective use of GA_3. The fresh weights and lengths of selected stalk segments were doubled and there was no effect on the pol: fiber ratio. These results were used to calculate a yield gain of 4.0 metric ton per pol hectare (Anon[4])

To resolve some of the reasons for variable responses in sugarcane, Bull[9] used growth chamber experiments to quantify the effects of temperature, variety, and plant age. The magnitude of the GA_3 responses was found to be a function of each variable. Greatest response was found with younger plants at lower temperatures.

Field trials in Australia with GA_3 confirmed many of the growth chamber results, established time-rate effects, and indicated a good potential for GA_3 to increase sugarcane yields. Significant gains (25% increases) in yields of sugar per hectare were obtained (Anon[5]). A major requirement for maximum response was an adequate time, usually a minimum of 3 months, between the last GA_3 application and harvest. The optimum amount of GA_3 was about 210 g per ha. Multiple applications were more effective than were single applications. No significant differences were noted in cane yields when the time between applications was varied from 3 to 9 weeks.

In field trials in Hawaii[23], the high variance in mill harvest yields made it difficult to assess the effects of GA_3 treatment. Nevertheless, GA_3-treated plots showed gains in about two-thirds of the tests. The average gain per hectare was 11.2 metric tons cane and 0.9 ton pol.

Greenhouse experiments in Puerto Rico expanded information on the post-stimulatory slow growth phase that sugarcane exhibits following GA_3-promoted growth (Alexander, *et al*[7], Mathur and Saxena[14]). This led to multiple applications of GA_3 in smaller doses as a method for avoiding the growth reduction (Alexander A.G.[8] and Singh[20]). Additional greenhouse experiments in the early 1970's included studies on possible enxymatic regulatory roles of GA_3 (Alexander[6] and Gayler and Glaziou[12]) and the interaction of GA with mineral nutrition (Alexander[6]) and growth inhibitors or ripeners (Yates[26,27]).

By 1975, the 20th year after the original work on the effect of GA_3 on sugarcane, several generalizations could be made:

1. The greatest increases of growth in response to GA_3 occur when sugarcane is growing under stress of cool weather or drought.

2. Although all sugarcane varieties respond to GA_3, considerable differences exist among varieties in the magnitude of response to a given amount.

3. The amount of GA_3, in a single application, required to produce maximum weight is a function of variety, environment and efficiency of application. Nevertheless, the maximum GA_3 per hectare should not exceed 210 g.

4. Maximum effectiveness of a given amount of GA_3 is obtained with multiple applications of a traditional amount.

5. The amount of fresh weight gain due to GA_3 is highly variable because it is a function of the plant interaction with the environment. However, the gain is generally around 11 metric tons per hectare and can be increase by optimizing the conditions listed above.

ADAPTATION TO HAWAIIAN CONDITIONS.

It is now necessary to expand the above summary of results with GA_3 on sugarcane to the particular cropping system practiced in Hawaii. As noted, the maximum effect of GA_3 on on sugarcane was seen when the cane was stunted or dwarfed by growing it under cool, growth-limiting conditions (Bull[9], Coleman[11] and Mongelard and Mimura[15]). Data presented in Fig. 1 show that stalk fresh weight, stalk length, and sugar content per stalk were greatly increased by GA_3 at lower temperatures but not at higher temperatures. GA_3 had almost no effect on these parameters when plants were grown at temperatures of 23°C or higher.

The annual mean temperature distribution and the volume growth rate of sugarcane in Hawaii show essentially coincident curves (Fig. 2). Growth rates are relatively high in the summer months when the mean temperature is about

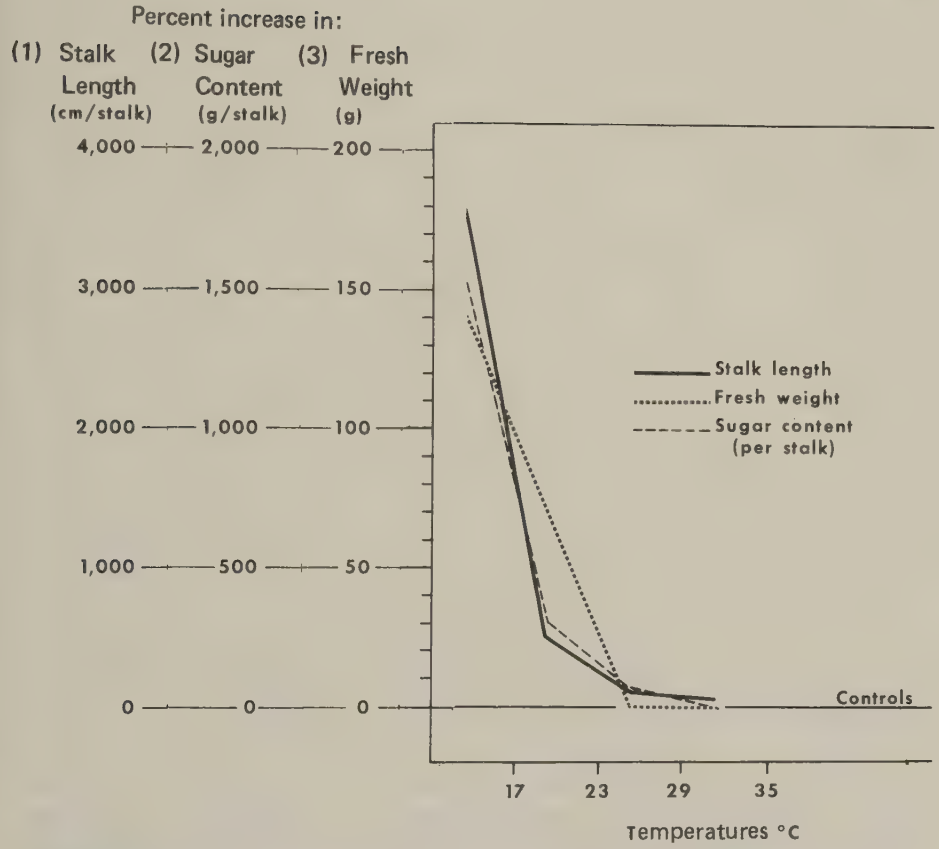

FIGURE 1. Effect of weekly doses of 0-02 mg/stalk of gibberellic acid on 3-month-old plants of sugarcane (W. Pindar) growing at various temperatures. Data expressed as a percent of the values of the controls not treated with GA_3. (Data from Bull, 1964.)

26°C and they are relatively low during the winter months when the mean temperature is just over 20°C (Stender[21]). While summer growth cannot be greatly increased by GA_3, because of the gibberellin x temperature interaction, that of winter can be significantly increased with GA_3.

The sugarcane crop in Hawaii is generally grown for 24 months. Thus, regardless of planting or ratooning dates, winter occurs during developmental stages of maximum growth potential (Fig.3)(Shaw and space Swezey[18]).The potential yield loss to slow growth during winter seasons can be extrapolated from a generalized growth curve obtained by averaging the growth curves of crops planted throughout the year (Fig. 4). If growth rates were not reduced by winter season, yields of the Hawaiian sugarcane corp would be expected to be increased by about 14% for each winter of the crop cycle (Moore[16]).

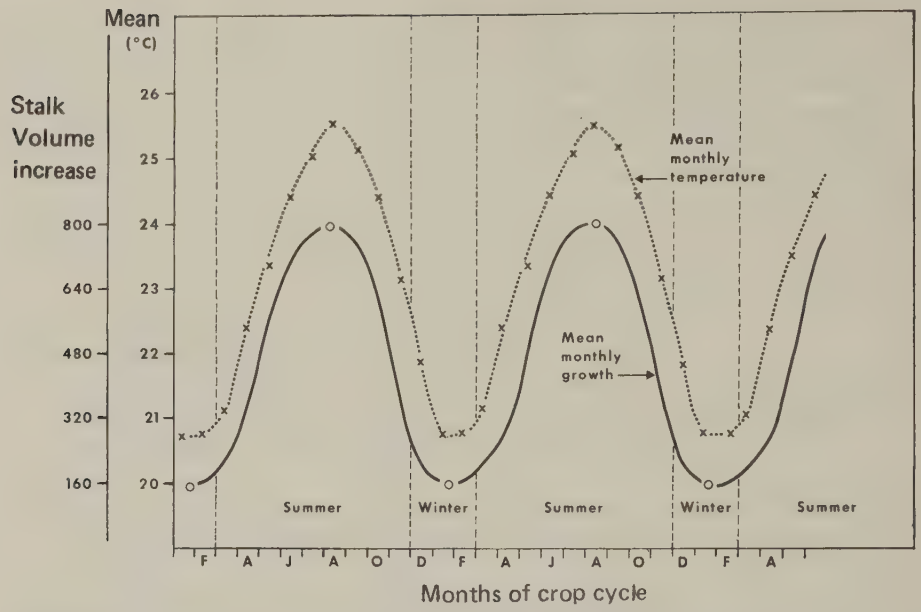

FIGURE 2. Relationship — between mean monthly temperature and the growth in volume of sugarcane. (Growth data from Stender, 1964.)

GA_3 has potential for reducing the winter loss, but the potential is limited in part by characteristics of sugarcane response to GA_3. It has been reported that GA_3 stimulates about 1 month of stalk growth and causes lowering of cane quality for about 3 months (Villareal and Santos[24]). It has also been demonstrated that for maximum results, a minimum of 3 months is required between the last GA_3 application and harvest Anon[5]. Additional time may be required if, as in Hawaii, chemical ripeners crop is scheduled for harvest early in the milling (Fig. 5). In addition, the inhibitory effect on tillering and the phytotoxic effects of high amounts of GA_3 on young sugarcane plants, (Moore[17] and Singh[20]) should preclude the use of this compound during the first winter of later-started crops. Thus, optimum use of GA_3 would be obtained by selectively treating crops in one winter or both, depending on the stage of development of the crop during the cool months.

Sugarcane varietal differences in response to GA_3 are well documented (Bull[9] and Moore[17]). We tested the growth responses of 10 Hawaiian commercial varieties to 1.4 or 4.2 mg GA_3 per stalk given in a single application to the upper leaf whorl. All varieties grew in response to both treatments and there were no statistically significant differences among them to either dose. However, there were significant differences among varieties in how they responded to the increase from 1.4 to 4.2 mg GA_3. For example, some varieties such as H50-7209, H58-4392 and H60-5657, grew significantly more in response to the 4.2 mg treatment than to the 1.4 mg

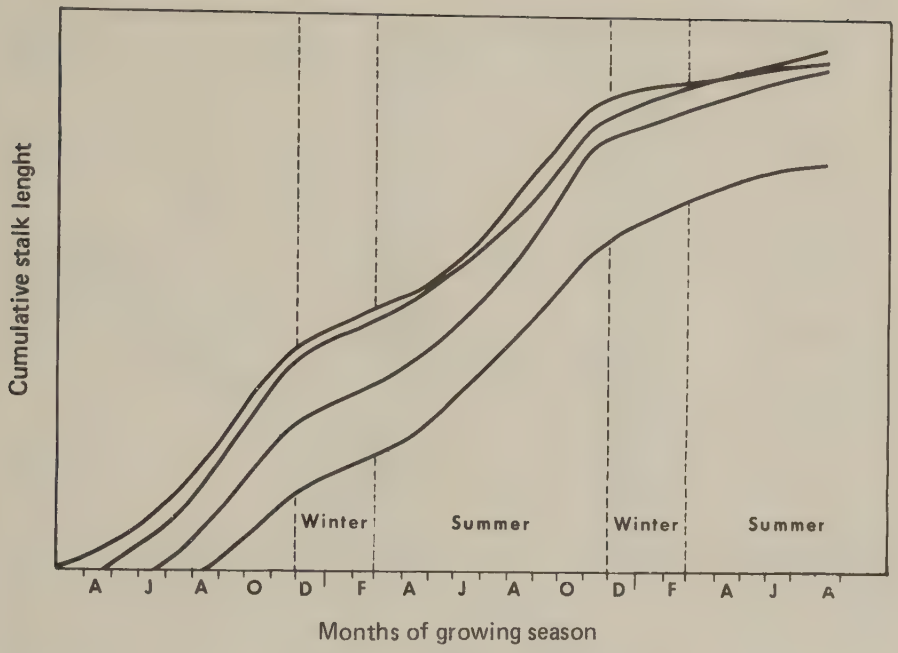

FIGURE 3. Effect of season on growth of sugarcane in Hawaii. The four curves represent crops planted four different times. (Modified from Shaw and Swezey, 1937).

treatment. Other varieties, however, e.g. H54-775, H56-278 and H56-4848, gave either a very small increase or actually grew less in reponse to the greater than to the lesser amount of GA_3 (Fig. 6). The former are varieties selected and cultured in lowland conditions under solar radiations and temperatures higher than those existing in the highland environment. The latter varieties are recognized as highland types. Thus, the responses of the varieties could be correlated with the environmental distribution of each.

By describing the environment in terms of the mean daily solar radiation, a correlation coefficient of 0.723 was found between the environmental zone of the variety and its mean weight increasing amounts of GA_3. It appears that the high-elevation varieties have a relatively low requirement for applied GA_3, while the low elevation varieties can utilize relatively higher amounts of GA_3. Consequently, in Hawaii we have placed emphasis on treating lowland varieties which are growing at their highest elevation range.

The amount of applied GA_3 required to produce maximum gains in sugarcane fresh weight and sucrose per stalk is a function of cultivar, environment, and physiological condition of the crop. Applications of GA_3 in excess of the amount which produces maximum increases in stalk fresh weight result in no additional growth increases and may at times result in adverse plant reactions such as loss

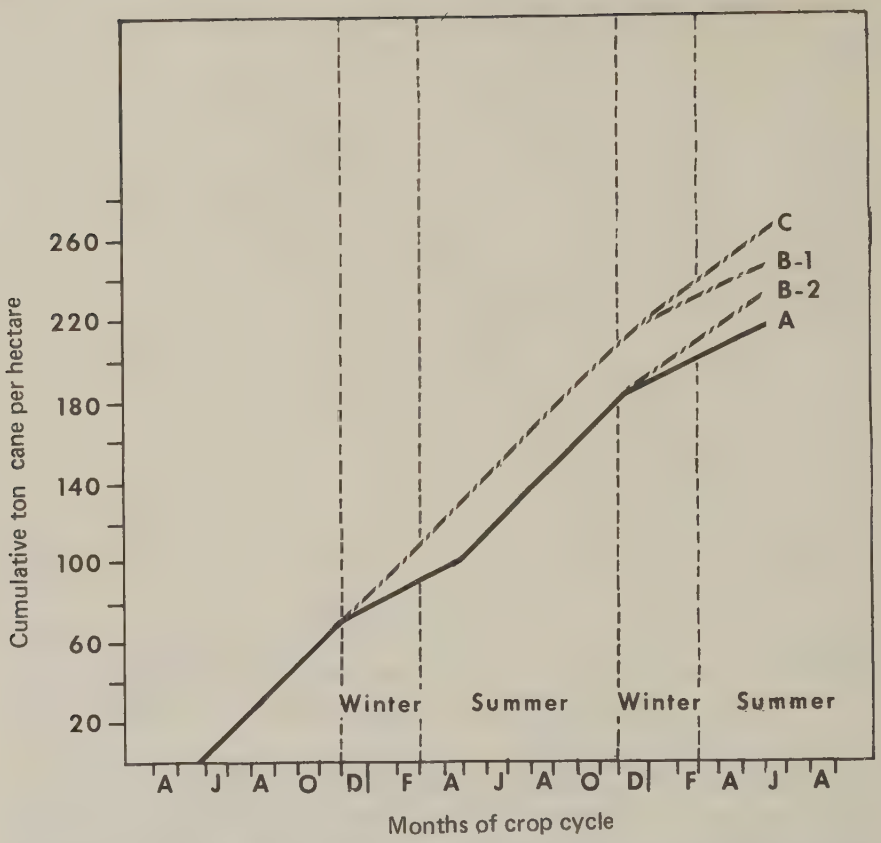

FIGURE 4. The effect of season and gibberellic acid treatment on theoretical yield of sugarcane. (A) Generalized crop growth curve and yield without GA_3. (B) Yield potential in response to GA_3 treatment one winter season: (B-1) GA_3 applied 1st winter; (B-2) GA_3 applied 2nd winter season. (C) Yield potential with GA_3 treatments both winter seasons. Note that GA_3 can be expected to elicit more growth in the 1st winter than the 2nd winter because by the 2nd winter the crop has nitrogen deficit.

of chlorophyll, reduced leaf area, stalk splitting and breaking, and less stalk fresh weight gain than by untreated stalks (Moore and Buren[17]). To overcome this problem, we used serial applications of fractional amounts of GA_3 to increase growth gains due to GA_3 while simultaneously reducing plant damage caused by the same amount of GA_3 given as a single application (Buren[10] and Moore[16]).

GA_3 treatment variables tested on a per stalk basis included:

1. Number of GA_3 applications
2. Amount of GA_3 applications

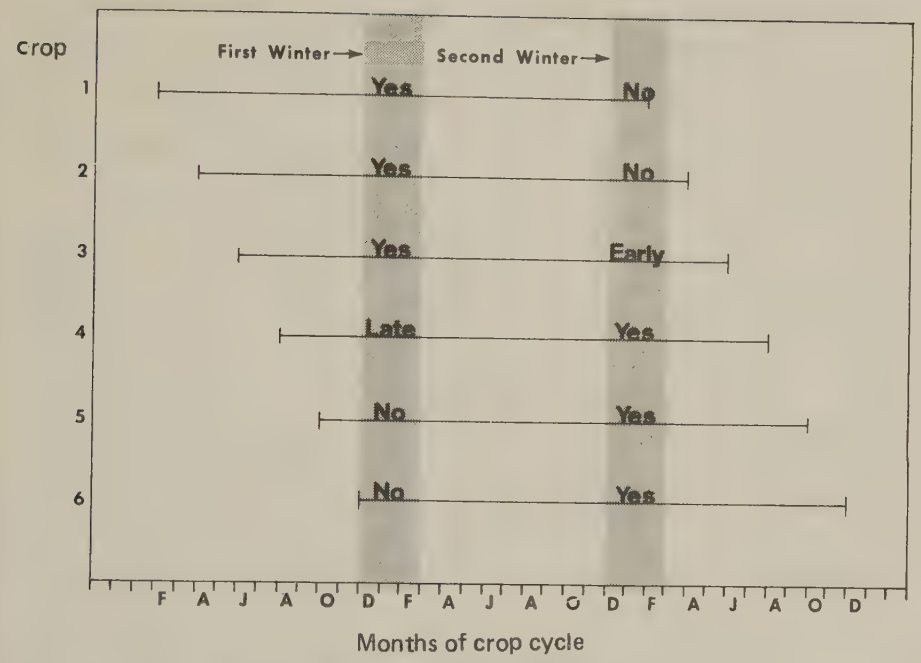

FIGURE 5. Time of crop starting and harvesting on a 24-month cycle and identification of which winter each crop has potential for treatment with GA_3.

3. Number of days between successive applications
4. Total amount of GA_3 applied.

A shorthand method will be use subsequently to designate each treatment, including information on each variable. For example, 3 x 0.5 @ 15 means that 3 applications of 0.5 mg GA_3 per stalk were made at 15-day intervals for a total of 1.5 mg GA_3 per stalk.

The results of an experiment designed to determine the optimum time interval between successive 1.0 mg GA_3 per stalk applications are presented in Table 1. The 1.0 mg GA_3 applications at 15 and 30 days showed significantly greater growth increases than a single 1.0 mg or a single 2.0 mg application and were greater than applications at 45-day intervals. Although the 15-day and 30-day interval treatments produced similar growth gains, the 15-day treatment resulted in considerably more dead and broken stalks, 18% vs. 2.8%. Most broken stalks apparently have grown rapidly following GA_3 application and produced internodes longer than the sheath normally enclosing them. Consequently, they were easily broken by the weight of the leaf canopy and wind.

Three or four applications of 0.5 mg GA_3 per stalk per application were tested at 15 and 30-day intervals to determine whether doses smaller than 1.0

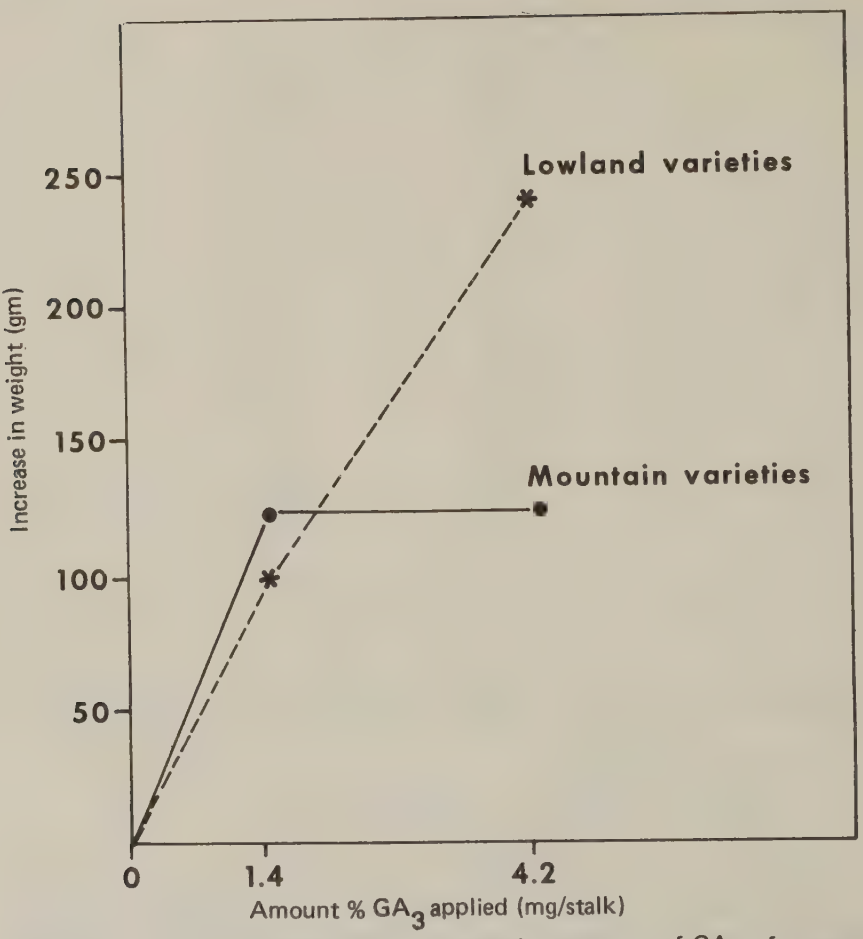

FIGURE 6. Dose response curves to increasing amounts of GA_3 of sugarcane varieties selected for culture in different environmental zones. Data represent the mean stalk fresh weight increase over untreated controls of 30 stalks of each of the three varieties of each type. Lowland varieties were H50-7209, J58-4392, and H60-5657, Highland varieties were H54-775, H56-278, and H56-4848.

mg per stalk might make more effective use of GA_3 (Table 2). The treatment schedule of 2 x 1 0 @ 30, determined to have produced the best sugarcane growth response in the previous experiment, was included in this test as a reference. The 15-day interval treatments produced more growth than the untreated controls but less than any of the 30-day interval treatments. The 3 x 0.5 @30 treatment, while not significantly different from the 2 x 1.0 @ 30 reference treatment, gave a greater weight gain and fewer dead stalks. Four applications of 0.5 mg at 30-day intervals produced significantly higher stalk fresh weights and lengths and fewer dead stalks than all other treatments.

TABLE 1. Mean difference (treatment minus check) in stalk fresh weight, stalk length, and percent dead stalks of seven commercial cultivars of sugarcane treated with one or two applications of gibberellic acid (GA_3)

Treatment schedule				Response		
No. of appl.	Mg GA_3 per appl.	Interval between appl.	Total amount GA_3/stalk (mg/stalk)	Mean fresh wt (g)	Mean length (cm)	Dead stalks (g)
1 x	1.0	0	1.0	96b*	14.0b	0.0
1 x	2.0 @	0	2.0	65bc	11.lb	6.0
2 x	1.0 @	15	2.0	203a	23.6a	18.2
2 x	1.0 @	30	2.0	180a	25.3a	2.8
2 x	1.0 @	45	2.0	85b	11.5b	4.3

* *Means within a column with a different letter are significantly different ($P < 0.10$) by Duncan's Multiple Range Test.*

TABLE 5. Mean difference (treatment minus check) in stalk fresh, weight stalk length, and percent dead stalks of seven commercial cultivars of sugarcane treated with 1.5 or 2.0 mg GA_3 per stalk in 2 to 4 applications at 15 or 30 day intervals.

Treatment schedule				Response		
No. of appl.	Mg GA_3 per appl.	Interval between appl.	Total amount GA_3/stalk (mg/stalk)	Mean fresh wt (g)	Mean length (cm)	Dead stalks (g)
3 x	0.5 @	15	1.5	198b*	31.8b	14.9
4 x	0.5 @	15	2.0	102c	27.3b	12.1
2 x	1.0 @	30	2.0	205b	30.7b	10.2
3 x	0.5 @	30	1.5	257b	30.0b	8.3
4 x	0.5 @	30	2.0	366a	46.4a	3.5

* *Means within a column with a different letter are significantly different ($P < 0.10$) by Duncan's Multiple Range Test.*

These multiple-application experiments show that the greatest sugarcane growth responses are from properly timed, frequent, small doses of GA_3 rather than from a single large dose. On the other hand, frequent windy and rainy winter days, the large area to be treated, and the cost of aircraft applications all favor few

TABLE 3 Effect of aerially applied gibberellic acid on length and fresh weights of six Hawaiian commercial cultivars of sugarcane.

Treatment	Cultivar	Number paired blocks	Stalk length (cm)			Stalk weight (g)		
			$\bar{X}_T$	$\bar{X}_C$	$\bar{X}_T$-$\bar{X}_C$	$\bar{X}_T$	$\bar{X}_C$	$\bar{X}_T$-$\bar{X}_C$
Single application	H50-7209	8	233	207	26*	1812	1613	214*
140 g GA_3	H54-775	3	179	155	24*	1131	963	168*
per hectare	H56-4848	2	230	200	30*	1497	1368	129*
	H57-5174	2	206	184	22*	1414	1268	146*
	H59-3775	18	225	195	29*	1437	1247	190*
	H60-8489	1	248	226	22*	1789	1639	150
		Means of CVs for single app.						
			233	196	27*	1514	1327	187*
Two applications	H50-7209	1	212	179	33*	1617	1440	231*
70g + 70g	H57-5174	4	205	173	32*	1378	1156	222*
GA_3 per heactare	H59-3775	7	281	239	42*	1835	1518	317*
made at about		Mean of CVs for two app						
30 day intervals			250	212	38*	1669	1391	278*

* *Difference between GA_3-treated and non-treated stalks significant at 0.10 level of probability as determined by standard Student's t-test*

TABLE 4. Effect of gibberellic acid on sugarcane quality as determined by pol-ratio analysis

Treatment	No. tests	Pol	Purity	Pol% cane
140 g/hectare				
Check	7	11.40	81.65	10.01
Treatment		12.28	89.20	10.79
$\triangle$T-C		0.88	7.55	0.78
70 g + 70 g/hectare				
Check	2	14.83	84.67	13.00
Treatment		14.87	85.38	12.97
$\triangle$T-C		0.04	0.71	–0.03

applications at high rates and at the longest possible interval. As a workable compromise, we settled on two applications spaced at 30-day intervals.

We established field tests to compare the effectiveness of a single application of 140 g per hectare with the effectiveness of two applications 70 g GA_3 per hectare (Table 3). This test was conducted on more than 1600 hectares of cane growing on each of the sugar producing islands of Hawaii and covered the major commercial varieties in the various ecological zones. There was a significant gain in length and fresh weight with either method for application; however, the divided application resulted in 49% greater weight gain. The increase in weight for the single application was 187 g per stalk and that for the multiple application was 278 h per stalk. At 70,000 stalks per hectare, these weight gains per stalk are equivalent to 13.1 and 19.5 metric tons cane per hectare. The quality of cane treated with GA_3 is at least equal to and generally better than that of untreated cane, provided that sufficient time (minimum of 3 months) is allowed between treatment and harvest (Table 4). The above calculated increases due to GA_3 for cane tonnage at a quality level where 9 tons of cane produce 1 ton of sugar would result in a calculated yield increase of 1.46 to 2.17 metric tons sugar per hectare.

OUTLOOK FOR GA_3 USE IN SUGARCANE

In Hawaii, where sugarcane is grown through a cool winter season, GA_3 can overcome winter stunting of growth to increase cane and sucrose yields. The magnitude of yield increase is not constant for it is a function of variety, environment (location and climate), and amount and method of GA_3 application. Nevertheless, we repeatedly measured a gain of around 230 g per stalk when GA_3 is used at the rate of two 70 g per hectare applications. This gain per stalk is equivalent to 16 metric tons cane per hectare or 1.5 to 2.0 metric tons sugar per hectare. The GA_3 we use is Abbot's "Pro-Gibb Plus" which currently costs about $80 per hectare plus application costs of around $15 per hectare. Thus, for an investment of $115 per hectare, we should received an average of 1.75 metric tons sugar worth about $460.00. This makes the use of GA_3 highly attractive in Hawaii.

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USO DE ACIDO GIBERILICO EN HAWAII PARA AUMENTAR RENDIMIENTOS DE CAÑA DE AZUCAR

Paul H. Moore

RESUMEN

Se presenta una reseña sobre el crecimiento y respuestas en rendi-

miento de caña de azucar tratadas con acido giberilico (A_3G). Consistentemente se obtuvieron aumentos sobre el testigo en peso verde del tallo de plantas tratadas con A_3G bajo las siguientes condiciones: (1) tratando las variedades que mejor respondian; (2) tratando los campos mas elevados; (3) aplicando el A_3G para coincidir con el invierno; (4) permitiendo suficiente tiempo antes de la cosecha para que madure el crecimiento producido por el A_3G y (5) aplicando el A_3G en dosis de 1.0 Mg o menos por tallo a intervalos de 15 a 30 dias.

Estas condiciones se alcanzaron en ensayos de campo en Hawaii donde se obtuvieron aumentos significativos en peso verde por tallo sin reduccion de calidad de la caña. Los aumentos en pesos eran comparables a aumento en rendimiento de 1.75 toneladas metricas de azúcar por hectárea. Por lo tanto, bajo condiciones cuidadosamente selecionadas el A_3G aparentemente pudiera resultar factible en Hawaii.

THE ROLE OF SIDE SHOOTS IN FLOWERED STALKS OF SUGAR CANE

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ABSTRACT

Sucrose yield and its components are compared from 6 to 27 weeks after anthesis in vegetative canes induced to flower artificially, and in flowered canes on which the side shoots were continually defoliated. The results confirm earlier reports that flowered canes had higher sucrose yield than vegetative canes early after anthesis, and that these differences gradually decreased. The difference in sucrose yield between the above two types of stalks was due primarily to the dry weight component and not to sucrose content.

Flowered stalks on which side shoots were defoliated showed an increasing loss of dry weight from 13 to 27 weeks after anthesis and consequently yielded significantly less sucrose than normal flower stalks. The reduction of dry weight was due solely to the DM% cane component as no difference in fresh weight was detected between the two types of flowered stalks. The reduction of dry weight in defoliated stalks was due to losses of both sucrose and fiber in the proportion of 2 to 1. The present investigation confirms the role of side shoots in maintaining sugar yield and sucrose content of flowered stalks. The physiological, agronomic and breeding implications of the results are discussed.

INTRODUCTION

It had been generally accepted up to recently, that flowering was deleterious to sucrose yield particularly if harvest was delayed (Davies and Vlitos)[1]. However, Gosnell and Long[3] found that flowering stalks were heavier and had a higher yield of sucrose than vegetative stalks in a natural population. The first two authors have shown that the effect of flowering on yield is complex and will depend on the following factors: variety, time of harvest after anthesis and environment (Julien and Soopramanien)[5]; and also interactions between these factors may be significant. In some environments flowering stalks outyielded vegetative stalks at anthesis, however, the differences gradually decreased as vegetative stalks differentiated new internodes which elongated and resulted in an increase of weight. The sucrose content and sucrose yield of flowering stalks were maintained for several months after anthesis. The hypothesis was therefore put forward that side shoots which developed on flowering stalks produced assimilates not only to maintain themselves

but also to sustain the mother stalk (Julien *et al*[6], Gosnell and Julien[4]). The present paper reports on an investigation to verify the above hypothesis.

MATERIALS AND METHODS

Crop and Environment

A second ratoon crop of the sugarcane variety S 17 harvested in July,1976 was used in the present investigation. The experimental site is at 480 meters above sea level on a humic ferruginous soil with a mean annual precipitation of 3600 mm.

Experimental Design

A split plot design was adopted; there were 4 blocks of 3 main plots, each sub-divided into 4 sub-plots. The main plots consisted of 4 rows, 10 meters long and the sub-plots 4 rows, 2.5 meters long. In all cases only the two inner rows were considered as experimental.

Treatments

The following treatments were allocated to the main plots:

(i) All canes were induced to remain vegetative by means of photo-periodic treatments which have already been described (Julien *et al*[6]) (Vegetative)

(ii) Flowered stalks on which side shoots were allowed to develop normally (Normal flowering)

(iii) Flowered stalks on which the side shoots were continuously defoliated so as to leave only leaf sheaths (Defoliated).

The four sub-plot treatments represented sampling dates at 6, 13, 20 and 27 weeks after anthesis respectively.

Selection of stalks

The percentage flowering of variety S 17 ranges from 30 to 80; it therefore follows that in the population induced artificially to remain vegetative, some of the stalks would have remained vegetative under natural conditions. Further, it has been shown that these naturally vegetative stalks, which are the more juvenile have a lower fresh/dry weight and sucrose yield than the mean of a vegetative population induced artificially (Julien *et al*[6]). Consequently, if a random sample of canes is taken from the population of induced vegetative stalks and compared to flowering stalks in the natural population, the comparison is based in favour of the flowering stalks. Comparison should be made between flowering stalks on one hand and induced vegetative stalks which would normally flower under natural conditions on the other.

This problem may be solved if the canes in the induced vegetative population

which would potentially flower could be detected and marked prior to initiation. In an attempt to determine the above the following experimental technique was adopted.

Above 7 weeks prior to initiation which usually takes place during the third week of March, the canes in all the experimental rows were tagged with different color codes depending on their number of internodes as defined (0-7, 8-9, 10-14, 15-19 and greater than 20). At anthesis, the % flowering was determined in each color group. The data was then used to select similar canes in the flowering and artificially vegetative population for comparison as will be explained in the results section.

Data recorded

In each sub-plot the following were recorded: number of leaves, number of internodes and leaf area. At the beginning of February all cane were marked at the last visible dewlap leaf and subsequently at the node substending the sheath of the marked leaf. At each sampling date, a sample of 15 canes was cut at this mark into top and bottom sections and prepared for analysis of pol % cane (de Saint Antoine[10]), fiber % cane (de Saint Antonine et de Froberville[11]) and Brix. From these primary variates dry matter (DM) % cane, pol % DM, fiber % DM, dry weight, sucrose and fiber per stalk were determined.

Statistical analysis

As development of side shoots started at the end of June, the first defoliation treatment coincided with the first sampling date in July. Hence, for that date, the defoliated treatment was identical to the normal flowering. Consequently, in the analysis of variance only three sub-plot treatments corresponding to the last three sampling dates were included.

RESULTS

Selections of stalks

The percentage flowering for the different groups of stalks are given in Table 1 which show that canes with less than 10 internodes did not flower. Consequently, only canes with more than 9 internodes are taken in the sample from the induced vegetative population.

Development of the plants

In the vegetative stalks very little elongation took place between August and December. In the flowered stalks no elongation could be expected but a decreasing trend in the total length per stalk was evident (Table 2). This is explained by the breakage and loss of the topmost internodes in the flowered stalks. In the vegetative stalks however, about eight extra internodes were formed over the August to December interval while leaf area per stalk dropped by about 34%. Leaf area of

TABLE 1. Number of internodes and intensity of flowering.

No. of internodes	% Flowering
0 – 7	0
8 – 9	0
10 – 14	70
15 – 19	76
< 20	80

*The leaf with topmost visible ligule was taken as attached at the base internode 1.

TABLE 2. Height, number of internodes and leaf area of vegetative (V), flowered (F) and defoliated stalks (D).

		Weeks after anthesis		
		13 +	20 ++	27 +++
Height (cm)	V	160	168	165
	F	208	191	179
	D	205	185	165
No. of internodes 110 canes	V	275	290	343
	F	230	225	220
	D	258	208	183
Leaf area ($100\ cm^2$)	V	49.0	36.1	32.7
	F	18.7	23.7	35.1
	D	—	—	—

+ August 29
++ October 20
+++ December 5

flowered stalks gradually decreased from anthesis to about August because of senescence of leaves. The non-defoliated flowered stalks produced about two side-shoots over the sampling period. An increase in size and number of leaves of these side shoots led to an increase of leaf area for the flowering stalk from 13 to 27 weeks (Table 2). In December the vegetative and non-defoliated flowered stalks had nearly similar leaf area per stalk.

Flowering vs vegetative stalks

At six weeks after anthesis sucrose yield of flowered stalks was higher than

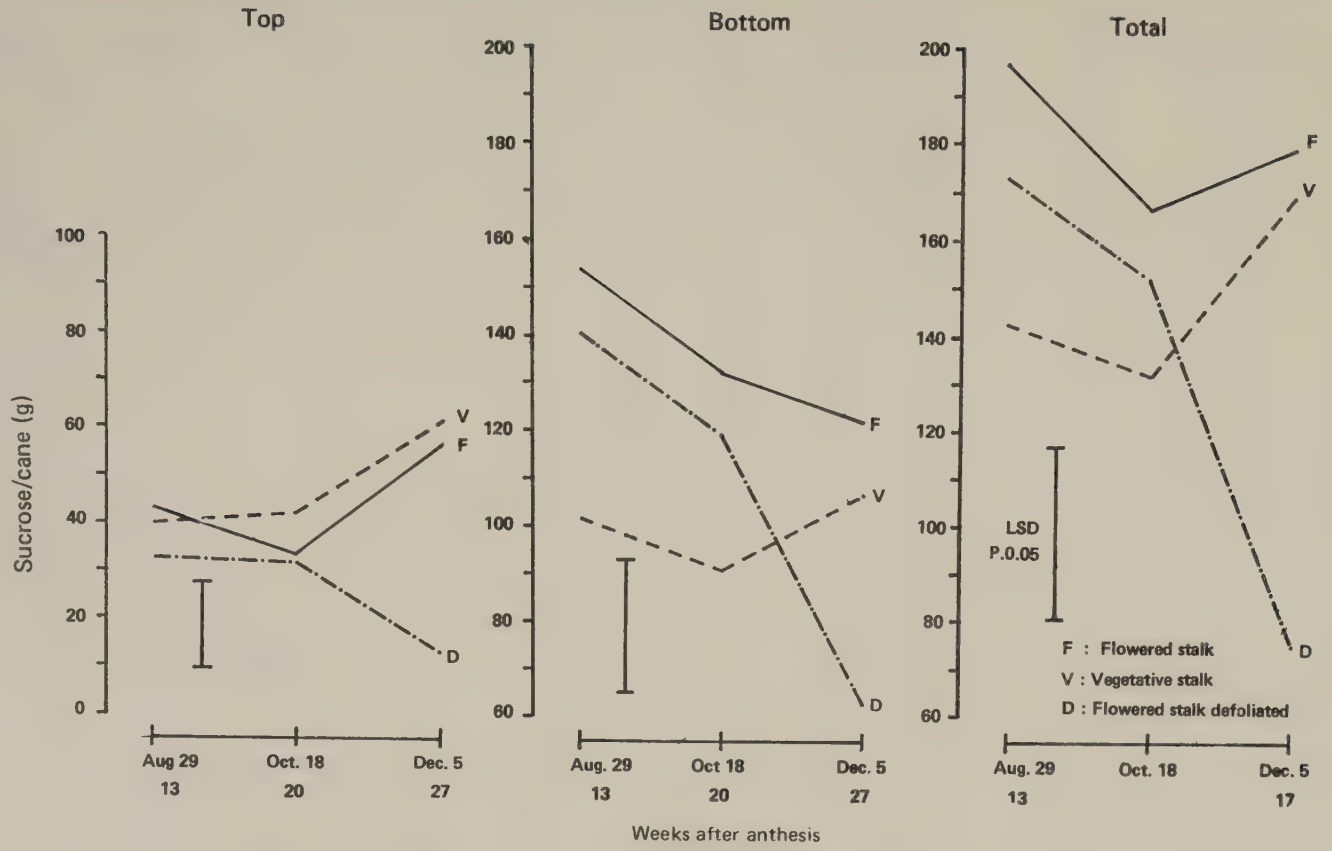

FIGURE 1. Evolution of sucrose per cane in top and bottom sections of flowering, vegetatitive and defoliated flowering sugarcane stalks.

that of vegetative stalks (162.5 tons/ha and 133.7 respectively); this was primarily due to the weight component as pol % cane of vegetative stalk was slightly higher than that of flowered (13.4 and 12.7 respectively).

The total sucrose yield per cane was significantly higher in the flowered stalk at 13 weeks after anthesis; this difference gradually decreased and was not significant at final sampling. This trend was primarily due to differences in the bottom section of the stalk (Fig. 1). Differences in sucrose yield may be analyzed either in terms of fresh weight and pol % cane or dry weight and pol % DM.

The differences in sucrose yield at 13 weeks were only due to differences in the fresh weight component, as pol % cane was higher in vegetative stalks but not significantly so (Tables 3 and 4).

Stem dry weight of vegetative stalks was lower than that of flowered stalks at 13 and 20 weeks after anthesis (Table 3) although DM content was higher in vegetative stalks (Table 4). This higher DM content of vegetative stalks was observed throughout the experimental period and in both the top and bottom sections of the stem. Stem dry weight of vegetative stalks increased from 13 to 27 weeks while that of flowered stalks decreased, explaining the absence of differences at final harvest.

TABLE 3. Comparisons of fresh and dry weight of stem in flowered (F), vegetative (V) and defoliated (D) stalks of sugarcane.

		Weeks after anthesis		
		13	20	27
Fresh Weight (g)	V	872 a	804 a	1023 a
	F	1281 b	1157 b	1130 a
	D	1265 b	1254 b	1020 a
Dry Weight (g)	V	298 a	291 a	349 a
	F	399 b	362 b	334 a
	D	381 b	361 b	248 b

Significant difference at P 0.05 between V, F and D are denoted by different letters following the figures.

Sucrose content (pol % DM) of vegetative stalks was generally stable throughout the experimental period (Fig. 2). In flowered stalks there was a reduction from 13 to 20 weeks which was followed by a sharp increase from 20 to 27 weeks. Sucrose content of flowered stalks was higher at 13 weeks, contributing to the higher

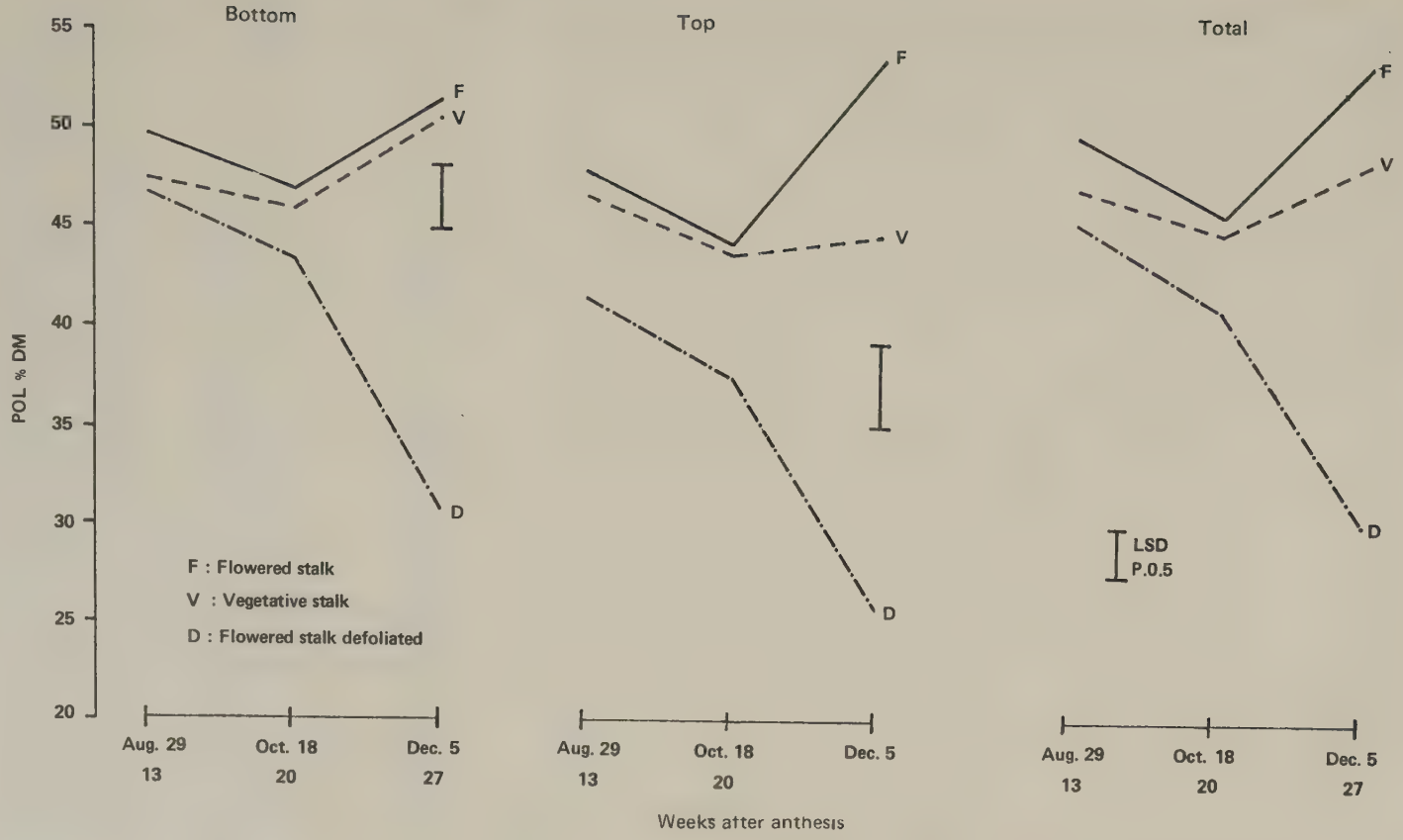

FIGURE 2. Evolution of pol % DM in top and bottom sections of vegetative, flowered and defoliated flowered sugarcane stalks.

TABLE 4. Comparison of Pol % cane, DM % cane, Fiber % cane and partitioning ratio (pol % DM/fiber % DM) of vegetative (V), flowered (F) and defoliated stalks (D)

		Weeks after anthesis		
		13	20	27
Pol % cane	V	16.2 a	16.4 a	16.5 a
	F	15.4 a	14.3 b	15.9 a
	D	13.7 b	12.2 c	7.4 b
DM % cane.	V	34.5 a	36.5	34.2 a
	F	31.1 b	31.3 b	29.8 b
	D	30.1 b	28.9 c	24.3 c
Fibre % DM	V	48.5 a	47.5 a	47.4 a
	F	45.2 b	45.0 b	43.6 b
	D	47.6 a	48.0 a	56.7 c
Pol % DM	V	0.98 a	0.95 ab	1.03 a
	F	1.10 b	1.02 a	1.23 b
Fibre % DM	D	0.96 a	0.88 b	0.54 c

Significant (P 0.05) differences between V. F, and D are shown by different letters following the figures

sucrose yield of flowered stalks at that time. It was significantly higher than vegetative stalks at 27 weeks but almost equal at 20 weeks, the top part of the cane contributing to the significantly higher sucrose content of the stalk.

Flowering vs Defoliated stalks

The total sucrose yield of flowering stalks was generally higher than the defoliated stalks; this difference was highly significant only for the final sampling at 27 weeks after anthesis and a similar trend being observed for both top and bottom sections of the stalk (Fig. 1).

This observed difference in sucrose yield was not due to a difference in fresh weight but was only attributed to the pol % cane component (Tables 3 and 4). In fact, there were significant differences of pol % cane in favour of the flowered stalk at all sampling dates; this being more marked in the top section of the cane. When sucrose content is expressed on a dry weight basis the above differences were even

more marked particularly at the final sampling (Fig. 2) The stem dry weight yield of flowered stalks was higher than the defoliated only at 27 weeks after anthesis; this difference was present in both the top and bottom sections of the cane stalks. The above differences were primarily due to lower DM content (DM % cane) in the defoliated stalks.

The lower sucrose content in defoliated stalks resulted from a reduction of dry matter content and a higher portion of the dry matter was in the form of fiber. The loss of dry matter in defoliated stalks from 13 to 27 weeks was due to losses of both fiber and sucrose; however, the losses of sucrose were two- fold higher than that of fiber in both top and bottom sections of the stalks (Table 5) explaining the higher amount of fiber at final harvest.

DISCUSSION

The results of this investigation confirm previous reports (Julien and Soopramanien[5]; Julien *et al*[6]) that flowered stalks may have a higher yield than vegetative stalks if harvested soon after anthesis; the superiority of flowered stalks is gradually lost as harvest is delayed.

The sharp drop of sucrose content at 20 weeks after anthesis coincides with the period when the leaf area of flowered stalks is at its minimum because all the leaves have senesced and those of side shoots are just starting to develop. This indicates a relation between leaf area and sucrose content. As leaf area of flowered stalks increased from 20 to 27 weeks, sucrose content also increased significantly.

TABLE 5. Gains and losses of DM, Sucrose and Fibre of defoliated stalks (g)

		Period (weeks after anthesis)		
		13 – 20	20–27	13–27
Top	Sucrose	– 0.1	– 19.8	– 19.9
	Fiber	+ 4.6	– 12.6	– 8.0
	D.M.	+ 6.0	– 36.0	– 30.0
Bottom	Sucrose	– 20.9	– 57.2	– 78.1
	Fiber	– 12.6	– 20.3	– 32.9
	D.M.	– 25.5	– 77.3	– 102.8
Total	Sucrose	– 21.0	– 77.0	– 98.0
	Fiber	– 8.0	– 32.9	– 40.9
	D.M.	– 19.5	– 113.3	– 132.8

Further, the sharp drop of sucrose content during the same period in defoliated stalks constitutes further evidence to support the relation between leaf area and sucrose content. Evidence has been presented to show that the loss of dry matter in defoliated stalks was due to both sucrose and fiber. The losses of sucrose are accounted for by the fact that the defoliated stalks produced very little assimilates to replenish the sucrose consumed in respiration, (Glover [2]).

Fiber content as determined in the method cited earlier measures insoluble substances which consist mainly of cellulose (25-30%), hemicellulose (12-18%) and lignin (8-12%) (Martin[8]). The loss of fiber implies that these substances are being degraded. A decrease of hemicellulose during ripening of bananas has been observed while the presence of the enzyme cellulase in ripe tomato fruit and also in pumpkin has been detected (Spencer[9]). It would therefore be of interest to follow the changes of cellulose and hemicellulose in defoliated shoots. The possible breakdown of these two constituents by microbial activity cannot be rejected and must also be investigated.

The losses of sucrose plus fiber in the bottom of the stalks were higher than the dry matter losses. This implies that part of the sucrose and/or fiber is being transformed in unknown substances which have contributed to dry matter. It would be of interest to investigate the nature of these products.

It is of significance to note that no difference in fresh weight between defoliated and flowered stalks was observed at 27 weeks although dry matter content was significantly lower in the former. Hence, the defoliated stalks had a much higher water content; a possible explanation is that transpiration losses in the dry summer months of November and December must have been considerably lower in the defoliated stalks which had a negligible leaf surface. The higher dry matter content of vegetative stalks compared to flowered stalks could also be partly attributed to differences in transpiration losses as leaf area was higher in vegetative stalks.

The present investigations confirm the hypothesis that the side shoots, or more precisely, their leaves play a dominant role in maintaining dry matter and sucrose content of flowered stalks in Mauritius. Long[7] observed large varietal differences in cane deterioration due to flowering which was possibly related to a differential rate of development of side shoots. Consequently, side shoots should be removed from flowered stalks, if at all, only at the time of harvest but not earlier. Furthermore, a heavily flowered field in which side shoot development is slow or negligible should be harvested soon after anthesis to avoid substancial losses of sucrose. On the other hand when side shoot development is good, harvest may be delayed several months after anthesis. In a selection program, the breeder should select high flowering varieties only if they develop side shoots. The rate of production of leaves on the side shoots should also be considered as an important criteria during the selection of high flowering varieties.

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EL ROL DE LOS BROTES LATERALES EN LOS TALLOS FLORECIDOS DE CAÑA DE AZUCAR.

M. H. R. Julien, G. C. Soopramanien, J. F. Martine and H. Medan

RESUMEN

En esta investigacion los contenidos de sacarosa y sus componentes son comparados desde 6 a 27 semanas despues que la antesis fue in-

ducida artificialmente en las cañas en cuales los brotes laterales fueron continuamente defoliados.

Los resultados confirmaron informes anteriores que las cañas florecidas tienen alto contenido de sacarosa que las cañas en crecimiento temprano despues de la antesis y que las diferencias gradualmente decrecian. La diferencia en contenido de sacarosa entre los tipos arriba mencionados de tallos se veia primeramente a los componentes peso y no al contenido de sacarosa.

Los tallos florecidos en los cuales los brotes laterales fueron defoliados en el momento de la perdida de peso seco desde las 13 a las 27 semanas despues del antesis, consecuentemente rindieron significativamente menos sacarosa que los tallos florecidos normalmente. La reduccion del peso fue debido solamente al componente DM % caña como no fue detectado ninguna diferencia en peso fresco entre los 2 tipos del tallos florecidos la reduccion del peso seco en los tallos defoliados, fue debido a la perdida de sacarosa y de fibra en la proporcion de 2 a 1. La presente investigacion confirma el rol de los brotes laterales en el mantenimiento de los contenidos de azucar y sacarosa en los tallos florecidos. Las inplicancias fisiologicas y agronomicas de los resultados son discutidas.

EFFECTS OF PREHARVEST BURNING ON CANE QUALITIES AS ASSESSED BY REAL ANALYSIS

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ABSTRACT

By real analysis, the burnt standing cane showed the best milling qualities under dry hot weather conditions. Both unburnt and burnt cane showed a decrease in juice and sugar extraction, an increase in the final bagasse % cane and sugar losses in the final bagasse. The mixed juice quality followed by real analysis showed slight changes in burnt standing cane and a little decrease in the burnt cut cane.

A drastic decrease in the quality of mixed juice took place before 3 days storage of the unburnt cut cane. The burnt standing cane showed continuous drop in brix and sucrose % juice, while other non-sucrose soluble solids % brix were nearly constant. In the unburnt cut cane both brix and non-sucrose solid increased while the sucrose decreased. The brix and the sucrose % juice increased substantially but other solids increased slightly. The Pol % cane and theoretical recovery showed a continuous drop after the first day in the burnt standing cane. In the unburnt cut cane, the decrease became clear after 3 days. The unburnt cut cane exhibited a continuous increase until the end of the test period. The burnt standing cane suffered the least deterioration losses whereas, the unburnt cane deteriorated more rapidly.

Estimation of the expected yield of both cane and sugars in tons per unit cultivated area showed that burnt standing and burnt cut cane gave closer results to that of fresh cane up to 3 days after treatment. The sugar yield in unburnt cut cane on the other hand, gave a lower result due to dryness and rapid deterioration during storage.

INTRODUCTION

Preharvest cane burning at present is practiced in the majority of the sugarcane producing countries, either to prepare cane for mechanical harvesting or to increase the efficiency of manual cutting. After burning and/or cutting, there may be a delay for variable periods of time before milling. Owing to

variable local conditions in the cane producing areas, the experimental results concerning the effects of burning and lapse of time after burning, on cane quality, whether standing or cut, are conflicting (Rizk and Normand [12]).

Preharvest cane burning may affect cane weight, milling qualities, juice quality, rate of sucrose inversion in cane and some of its industrial qualities (Waddall[8], Young[20], Turner and Rojas[17] Samuels and Coyers[13], Patro[11], Rizk and Normand[12], Amarel and Dearmes[1], Fernandez[6], Amin *et al*[2], Wood *et al*[19], Sloane and Rhodes and Sayed *et al*[16]).

All investigations reviewed on such effects were assayed by apparent analysis which might lead to conflicting results under various conditions. This study was conducted to investigate the effect of cane burning on mixed juice qualities when burnt cane is left standing in the field or burnt and immediately cut and exposed to delayed milling under the dry subtropical conditions of Upper Egypt. The real analysis will be used in the study. Results were compared with those of freshly cut cane and cut unburnt cane exposed to the same conditions.

MATERIALS AND METHODS

This study was carried out in Kom-Ombo sugar factory. The second ratoon crop of the commercially important cane variety N C O 310 was selected for the study. The cane was planted and treated according to the traditional agricultural practices of the region.

Tests on the effects of preharvest burning on cane qualities, milling qualities and rate of deterioration with the elapse of time after harvest, were investigated. These studies were carried out during March, April and May in order to cover the prevailing weather conditions throughout the milling season in Kom-Ombo region. Such region is subtropical and lies between latitude 24°.24 and longitude 33°. It is characterized by dry weather with long hot summer and short winter during March is about 30.2; 37.2 for April and 39.7 for May. The average minimum temperature during the same months are 10.7, 14.8 and 18.6, respectively, with an average relative humidity of about 36% in March, 27% in April and 25.8% in May.

At the test dates, canes were 12, 13 and 14 months of age. An area of ¼ faddan of erect cane, homogenous in vegetative growth, was used at each data of the three test periods and at constant fastening periods.

Sampling

The procedure adopted for cane sampling was that described by Sayed[2,14], except that the mother samples were subsampled before milling to 30 kg samples.

Half the area for each date of analysis were burned, then the samples for each of the four treatments tested was secured as follows:

(1) From the unburnt standing area nine mother samples were cut, hand stripped, topped and stored under open field conditions to represent the unburnt harvested cane.

(2) From the burnt standing half area, nine mother samples were secured as mentioned above and stored under open field conditions to represent the burnt cut cane.

Both the unburnt and burnt standing canes were bundled to avoid lodging. Three samples of 30 kgs. from each of the previously mentioned four treatments were crushed for analysis at 1, 3, 6 and 9 days intervals after cutting and/or burning. Direct analysis of cane was done according to Sayed *et al*[15]. Juice extraction was done according to Hemaida *et al*[8].

Juice analysis

Mixed juices were analyzed for each brix, real sucrose, reducing sugar and ash by electrical conductivity, by the methods described by Meade and Chen[9]. Total nitrogen of the juice was determined by Gunning method A.O.A.C.[3].

Total acidity as acetic and gums were assayed according to Browne and Zerban[4]. Sugar percent final bagasse was determined by the method of the Egyptian Sugar and Distillation Company, Chemical Control. Then the various indices for milling, juice and cane qualities were calculated according to Meade and Chen[9]. Theoretical sugar recovery and sugar losses in final molasses were calculated by Winter-carp-formula as simplified by Hebert[7].

Percentages of decreases or increase in real brix related to that of fresh cane were considered as the supposed increases or decreases in weight of cane in tons/unit cultivated area respectively. The average yield of fresh mature cane in Egypt is 40 tons/Faddan.

RESULTS

Effect on mixed juice quality

The important mixed juice quality indices, namely real brix, clerget sucrose, real purity, and glucose ratio and other characteristics such as total acidity, gums % brix, reducing sugars % brix and total nitrogen % brix, were determined and/or calculated in the different treatments.

Table 1 shows the changes in brix, sucrose, purity and glucose ratio.

A steady increase in real brix with elapse of time after harvest is shown in both burnt and unburnt cut cane. The brix of the burnt cane increased from 22.54 degrees in fresh canes to 30.35 degrees after 9 days burning and cutting. Conversely, the burnt standing cane showed a continuous drop in brix, as the time it was left standing in the field after burning was prolonged

Real sucrose percent juice behaved similarly in the burnt cut cane exhibiting an increase from 20.53% to 26.00% by the end of the 9 days of storage. Both unburnt cut cane and burnt standing cane showed a drop of 2.11 and 1.19 degrees in sucrose % juice, respectively.

The burnt standing cane showed the minimum undesirable changes in real purity and glucose ratio followed by the burnt cut cane. The unburnt cut cane suffered a more drastic drop in purity from 91.1 to 76.0 degrees and an inverse in glucose ratio from 14.5 to 20.0% after 9 days of storage.

TABLE 1. Average real brix, clerget sucrose, real purity and glucose ratio of mixed juice

Parameters	Treatments	Days after treatments				
		0	1	3	6	9
real brix	Check (fresh cane)	22.54	—	—	—	—
	burnt standing cane	—	21.36	21.45	21.19	20.84
	burnt cut cane	—	22.97	23.99	26.55	20.35
	unburnt cut cane	—	22.58	23.48	24.71	25.44
clerget sucrose	Check (fresh cane)	20.53	—	—	—	—
	burnt standing cane	—	19.42	19.47	18.80	18.42
	burnt cut cane	—	20.88	21.77	23.24	26.00
	unburnt cut cane	—	20.14	20.36	19.32	19.34
real purity	Check (fresh cane)	91.1	—	—	—	—
	burnt standing cane	—	90.9	89.6	88.7	88.3
	burnt cut cane	—	90.9	90.7	87.4	85.7
	unburnt cut cane	—	89.2	86.7	82.7	76.0
glucose ratio	Check (fresh cane)	1.43	—	—	—	—
	burnt standing cane	—	2.07	2.18	3.04	3.82
	burnt cut cane	—	1.86	2.38	4.11	5.02
	unburnt cut cane	—	2.40	6.41	15.31	20.00

Data are average of 9 observations

Comparing the changes in the different parameters studied, it could be seen that the burnt cut cane showed the higher brix and sucrose % juice as a result of concentration while sucrose inversion was at a minimum. However, in the unburnt cut cane, the increase in the brix of the juice was not accompanied with a similar increase in sugar percent juice due to sucrose inversion which overcame sucrose concentration as a result of dryness. The net result was inversion of sucrose.

The burnt standing cane suffered a marked drop in both brix and sucrose percent juice due to changes in the physiological status of the plant under the effect of burning. Considering the drop in purity and increase in glucose ratio as measures of sucrose inversion in sugarcane, it could be proved that the unburnt cut cane deteriorated earlier and at a higher rate than the burnt cut cane. The burnt standing cane kept the best juice quality up to 9 days.

TABLE 2. Average total acidity, gums % brix, reducing sugars % brix and total nitrogen % brix of mixed juice.

Parameters	Treatments	Days after treatment				
		0	1	3	6	9
Total acidity m. gm/L	Fresh cane (Check)	660	–	–	–	–
	burnt standing cane	–	728	728	–	770
	burnt cut cane	–	724	751	1074	1228
	unburnt cut cane	–	775	853	1134	1222
Gums % brix	Fresh cane (check)	2.56	–	–	–	–
	burnt standing cane	–	2.43	3.14	3.70	4.26
	burnt cut cane	–	2.56	3.51	3.52	3.53
	unburnt cut cane	–	3.26	3.42	–	3.88
Reducing sugars % brix	Fresh cane (Check)	1.30	–	–	–	–
	burnt standing cane	–	1.88	1.95	2.70	3.37
	burnt cut cane	–	1.69	2.16	3.59	4.30
	unburnt cut cane	–	2.17	5.56	12.66	15.20
Total nitrogen % brix	Fresh cane (Check)	0.29	–	–	–	–
	burnt standing cane	–	0.23	0.27	0.25	0.29
	burnt cut cane	–	0.21	0.22	0.22	0.26
	unburnt cut cane	–	0.28	0.32	0.38	0.34

Data are average of 9 observations

These findings by real analysis confirmed and agreed with those reported by Waddel[18], Young[20], Patro[11], Rizk and Normand[12], Amin *et al*[2] and Sayed *et al*[15], while Turner and Rojas[17], Samuels and Cayera[13], and Amaral[1] reported different results which may be due to the different local weather conditions.

Data in Table 2 demonstrates the changes in total acidity, gums % brix, reducing sugars % brix, and total nitrogen % brix in the various treatments.

Total acidity increased in the whole treatments, being pronounced in both burnt cut and unburnt cane.

Gums content increased with time in the various treatments, being more pronounced in the burnt standing cane where it increased from 2.56 to 4.26 % brix by the end of the storage period.

Reducing sugars % brix showed a steady increase with the time lapse after treatments. The unburnt cut cane suffered a more drastic increase by the end of 9 days.

The early increase in the total acidity, gums content and reducing sugars % brix, confirms the faster deterioration rate of the unburnt harvested cane over the other treatments.

Data in Table 3 show the ash % brix, total non-sucrose solids percent brix and the calculated sugar losses in final molasses percent sugar in cane.

TABLE 3. Average ionic Ash % brix, total non-sucrose solids % brix and the corresponding sugar losses.

Parameters	Treatments	Days after treatment				
		0	1	3	6	9
Ash % brix	Fresh cane (Check)	2.95	–	–	–	–
	burnt standing cane	–	2.89	2.86	2.57	2.38
	burnt cut cane	–	2.87	3.97	3.02	2.47
	unburnt cut cane	–	3.07	2.90	2.68	2.64
Total non-sucrose Solids % brix	Fresh cane (Check)	8.9	–	–	–	–
	burnt standing cane	–	9.1	10.4	11.2	11.7
	burnt cut cane	–	9.1	10.3	12.6	14.3
	unburnt cut cane	–	10.8	13.3	17.3	24.0
calculated sugar losses in final molasses % Sugar in cane	Fresh cut cane	3.84	–	–	–	–
	burnt standing cane	–	3.82	3.82	3.95	3.96
	burnt cut cane	–	3.94	3.92	4.14	4.40
	unburnt cut cane	–	3.80	4.06	4.63	4.68

Data are average of 9 observations.

The data indicate that the burnt standing cane was similar to the fresh cane in terms of such characteristics, since sucrose losses in final molasses were more or less constant through the 9 days.

In the burnt cut cane, both sucrose in final molasses and total non-sucrose solids, increase with time lapse after treatment. Unburnt cut cane showed bigger changes. It could be stated that burnt standing cane kept the best juice quality, followed by the burnt cut cane, while unburnt cut cane must be milled as soon as possible, to avoid ill-effects on juice quality.

The results are in agreement with those reported by Sayed *et al*[15].

Effects on milling qualities

Table 4 shows the changes in the calculated cane milling qualities in the different treatments, namely mixed juice extraction, sugar extraction and sucrose lost in final bagasse.

TABLE 4. Cane milling qualities as affected by different treatments.

Milling qualities	Treatments	Days after treatment				
		0	1	3	6	9
Mixed juice % cane	Check (fresh cane)	91.0	–	–	–	–
	burnt standing cane	–	90.9	91.4	89.7	90.3
	burnt cut cane	–	89.9	88.0	84.7	80.4
	unburnt cut cane	–	92.0	91.1	89.1	89.0
Final bagasse % cane	Check (fresh cane)	33.4	–	–	–	–
	burnt standing cane	–	34.2	33.6	35.4	34.7
	burnt cut cane	–	35.3	37.2	40.3	44.6
	unburnt cut cane	–	33.0	34.0	35.9	36.0
Sugar final bagasse % sugar in cane	Check (fresh cane)	5.13	–	–	–	–
	burnt standing cane	–	5.59	5.62	6.10	5.80
	burnt cut cane	–	6.10	7.50	9.64	12.40
	unburnt cut cane	–	4.80	5.20	6.47	6.40
Sugar extracted % Sugar in cane	check (fresh cane)	94.87	–	–	–	–
	burnt standing cane	–	94.41	94.38	93.9	94.2
	burnt cut cane	–	93.9	92.50	90.38	87.6
	unburnt cut cane	–	95.2	94.8	93.53	93.6

Data are average of 9 observations.

Burnt standing cane kept its milling qualities unchanged until the end of the test period. In the burnt cut cane, the mixed juice % cane and the percentage of sucrose extracted, decreased while the final bagasse % cane and the loss of sugar in the final bagasse increased from 33.4 to 44.6 and from 5.13 to 12.4%, respectively, by the end of the 9 days period. The milling qualities of the unburned cut cane took place in between.

Patro[11], Amin *et al*, and Sayed *et al*[15] reported that burnt standing cane gained in weight after burning. This may explain the minimum decrease in juice and sugar extraction until 9 days after burning. Other investigators (Rizk and Normand[12]) reported that burnt standing cane gave lower juice extraction than normal cane. The lower juice extraction in the burnt and unburnt cut cane may be due to dryness.

Sayed *et al* [15] attributed the nearly unchanged sucrose extraction in the burnt standing cane to the high extractable juice due to dilution and the inhibition of invertase activity. It was lowered in unburnt harvested cane mainly due to sucrose inversion and as a result of the changes in the characteristics of cane fibers as a result of burning and storage (in the case of burnt harvested cane).

Pablo Noriega Experimental units in Cuba, (Sayed *et al*[15]) in Egypt, reported that cane burning and/or storage after harvesting increase final bagasse % cane and sugar losses in final bagasse percent sugar in the cane.

Table 5 shows the changes in quality parameters of the different treatments as translated to the calculated Pol % cane, theoretical recovery and expected yields of cane and sugar per unit cultivated area.

The data shows that the Pol % cane and the theoretical recovery of burnt cut cane increased with the time lapse, but the expected yield of cane/unit cultivated area decreased. For burnt standing cane, the Pol % cane and the theoretical sugar recovery decreased while the expected yield of cane/unit cultivated area increased as the period was extended after treatment. The burnt standing cane gave higher expected tons of sugar per faddan than the burnt cut cane. Both burnt standing cane and burnt cut cane gave estimated sugar yield (tons/faddan) quite near to fresh cane up to period of 3 days after treatment, regardless of the high sugar losses in final bagasse and molasses. The unburnt cut cane showed a decrease in Pol % cane, theoretical recovery and expected yield of cane and sugar/faddan with the time lapse after treatment.

TABLE 5. Average Pol % cane, theoretical recovery, expected yields of cane and sugar per faddan.

Treatments	Days after treatment	Pol % cane	Theoretical sugar Recovery	Expected tons of cane/ Faddan	Expected tons of sugar/ Faddan
Fresh cane (Check)	0	18.04	14.70	40.0	5.880
Burnt standing cane	1	17.17	13.89	42.21	5.862
	3	17.30	13.89	41.86	5.814
	6	16.49	13.28	42.55	5.650
	9	16.16	12.99	43.26	5.620
burnt cut cane	1	17.90	14.72	39.25	5.778
	3	18.78	15.56	37.58	5.847
	6	19.54	16.38	33.96	5.562
	9	21.19	18.05	29.71	5.362
unburnt cut cane	1	17.98.	14.36	39.93	5.734
	3	17.76	14.23	38.40	5.464
	6	16.41	12.75	36.49	4.652
	9	16.70	12.55	35.44	4.448

— *Data are average of 9 observations*
— *1 Faddan = 4200 m^2*

CONCLUSION

Taking all the previous parameters and quality indices of mixed juice and milling qualities of treated cane, it can be concluded that burnt standing cane exhibited superior milling and juice qualities over burnt cut cane. Unburnt cut cane showed inferior qualities with time lapse after treatment.

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EFECTOS DE QUEMAS DE LA COSECHA SOBRE CALIDADES DE CAÑA DETERMINADAS POR ANALISIS REALES

Adel M. S. Saleh y Gad El-Kareem Sayed

RESUMEN

Bajo condiciones climaticas secas y calurosas la caña quemada en pie dio las mejores calidades de molienda, mediante analisis reales. Tanto la caña sin quemar como la quemada mostro una merma en jugo y extraccion de azucar y ún aumento en bagazo final % caña y perdidas de azucar en bagaso final. La calidad del jugo mezclado seguido mediante analisis reales mostro pequeños

cambios en caña quemada en pie en comparacion a una pequeña merma en caña cortada y quemada. Una baja drastica en la calidad del jugo mezclado ocurrio antes de los tres dias en caña cortada sin quemar. La caña quemada en pie mostro una continua baja en Brix, sacarosa % jugo con casi constantes solidos solubles % Brix no-sacarosa. En la caña cortada sin quemar tanto los Brix como los solidos no-sacarosa aumentaron mientras que la sacarosa disminuyo. El Brix y la sacarosa % jugo aumentaron substancialmente pero otros solidos aumentaron ligeramente. El Pol % cane y recuperacion teorica mostraron una merma continua despues del primer dia en la caña quemada en pie. En la caña cortada sin quemar la merma fue evidente despues de 3 dias. La caña cortada sin quemar mostro un aumento continuo hasta finalizar el periodo de prueba. La cana quemada en pie sufrio las menores perdidas en deterioro mientras que la caña cortada sin quemar se deterioro mas rapidamente que la caña cortada quemada.

MATURITY PATTERN IN FIELDS-IRRIGATED WITH FILTER CAKE WATER

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ABSTRACT

The ripening of sugarcane cul H32-8560 irrigated with filter cake water was studied in Palmillo III and Viudas in the Casa Grande Cooperative located on the Northern coast of Peru.

The soil was alluvial, medium textured, calcareous, well drained, without salinity problem, high organic matter and NPK and high cation exchange capacity.

Pol increased with age linearly and was not affected by Pan Evaporation (Eo), supply of nutrient by irrigation, and drying before harvesting. Also, purity and reducing sugar show maximum ripening independent of nutrient and drying. The peak appears approximately between 100 and 130 days after the lowest Eo.

Filter cake water provided the equivalent of N at 60 and 145 Kg/ha at Palmillo and Viudas respectively.

INTRODUCTION

In the sugarcane industry, it is commonly accepted that the quality of sugarcane is increased when plant growth stops (Sund[21], Humbert *et al*[10], Alexander and Samuels in Alexander[1]), accumulating sucrose instead of being used for vegetative growth. Fauconnier and Bassereau[8], Humbert[9], Lakshmikanthan[13] and Thomas[22] indicated that the quantity is decreased with N applications which promotes vegetative growth, although, Fauconnier and Bassereau[8] in Mauritius and Bordon (in Humbert[9]) indicated that when there is a great quantity of N in the soil quality is improved. On the other hand, Samuels *et al.* (in Humbert[9]), Singh and Singh[20], and Rosario *et al*[18] indicated that the quantity of nitrogen does not change the quality of sugarcane.

Alexander[1,2] stated that the increase of quality is the result of biochemical changes that occur when the plant is experiencing "stress". This stress can be caused by low temperatures, decrease in the water supply and deficit of nutrients, mainly NO_3, P,K and Ca. Alexander believes that it is not necessary that the

growing rate of the cane ceases for ripening, as it was believed before, but distinct metabolic regimes should be created.

Outward indications of cane stress such as stunting or other visible symptoms are in fact manifestations of biochemical changes which have occured much earlier; the causal agents could return to their normal level after. This could be an answer to the contradictory results described previously between N applications and cane quality, or they could be explained by Humbert[9] in an extensive review indicating that N applications must be early, and so avoid sugarcane quality to be affected. Fauconnier and Bassereau[8] agree that the early application is important.

With the aim of eludicating if the early absorption of N affects cane quality positively, we studied maturity behavior with time in fields irrigated with filter press mud water ("agua de cachaza"), rich in nutrients, specially N, and it is applied until near harvest, when cane ripens. Valdivia *et al*[25] found that later applications of N did not affect cane quality, and Valdivia *et al*[24] showed that ripening induction in Peru can be induced by a low potential evapotranspiration, in spite of maintaining the crop constantly under irrigation.

The filter press mud water used in Peru for irrigation is in fact a mixture of vinaza (sugarcane alcohol factory waste effluent), settlement waste water and sugar mill effluent. It has a high concentration of N, P, K and other nutrients (Valdivia *et al*[23]) and there is no response to N fertilization in fields irrigated with this water in contrast to fields that are irrigated with normal water. International references about the use of filter press mud water, are scarce. In Queensland field applications of mollasses diluted in filter press mud and irrigation water were made (Kerr[12]). However, there is plentiful bibliography about the use of filter press mud (solid) like fertilizer, in South Africa (Dodds[6]; Du Toit[7], Alexander[3]), in Puerto Rico (Oben[15], Mc Connie *et al*[14], Samuels and Capo[19], Samuels and Landrau in Alexander[3]), in Jamaica (Innes[11]), in Guyana (Evans, in Davies and Vlitos[5]) in Colombia (Ramos[17]) in Cuba (Aloma *et al*[4]), and in Trinidad (Prasad[16]).

MATERIALS AND METHOD

The work was conducted in Casa Grande Agrarian Cooperative, located in north coast of Peru (Chicama valley), in the fields Palmillo III and Viudas planted with cane H32-8560.

Soils are alluvial, medium textured, calcareous, without salinity problems, well drained, well provided with organic matter and NPK, and have a high exchange capacity. Both fields were fertilized with different N rates in order to study the response of sugarcane to N fertilization in fields irrigated with filter mud water. In Table 1 we can see the average results of the chemical analysis of the filter press mud water used.

Starting at 240-290 days after planting, four samples of cane per plot were

TABLE 1. Chemical composition of filter cake water, applied to experimental fields.

Characteristics	Palmillo $\bar{X} \pm s$	Palmillo Maximum value	Palmillo Minimum value	Viudas $\bar{X} \pm s$	Viudas Maximum value	Viudas Minimum value
EC mS/cm	1.37 ± 0.46	2.5	0.9	1.77 ± 0.54	2.5	0.9
pH	7.3 ± 0.8	8.0	5.3	7.2 ± 0.8	7.9	6.3
Total N mg/l	14.5 ± 12.7	36.4	3.1	24.4 ± 9.3	37.2	11.2
Ca^{2+} "	136.6 ± 42.1	215.0	96.5	163.3 ± 54.5	232.6	73.2
Mg^{2+} "	37.8 ± 12.7	62.5	23.5	54.8 ± 20.1	83.2	26.3
K^{+} "	134.3 ± 95.4	370.0	55.5	170.5 ± 68.4	272.1	66.5
Na^{+} "	46.2 ± 13.1	72.0	26.5	83.7 ± 83.7	107.6	38.4
Fe^{2+} "	3.0 ± 2.9	10.0	0.1	2.6 ± 1.9	5.0	0.0
NH_4^{+} "	2.4 ± 1.2	4.7	0.7	4.2 ± 1.3	5.1	2.0
NO_3^{-} "	5.1 ± 4.3	17.4	0.0	7.1 ± 4.1	12.4	2.5
PO_4^{3-} "	12.7 – 15.0	48.8	0.6	7.9 ± 6.8	19.1	0.0
Cl^{-} "	82.0 ± 48.6	202.1	35.5	103 ± 45.7	184.4	42.6
CO_3^{2-}	0.0	0.0	0.0	0.0	0.0	0.0
HCO_3^{-} "	456 ± 103.7	646.7	308.1	673.1 ± 229.4	903.1	274.6
SO_4^{2-} "	220 ± 134.5	473.1	30.0	274.4 ± 123.0	388.6	114.8

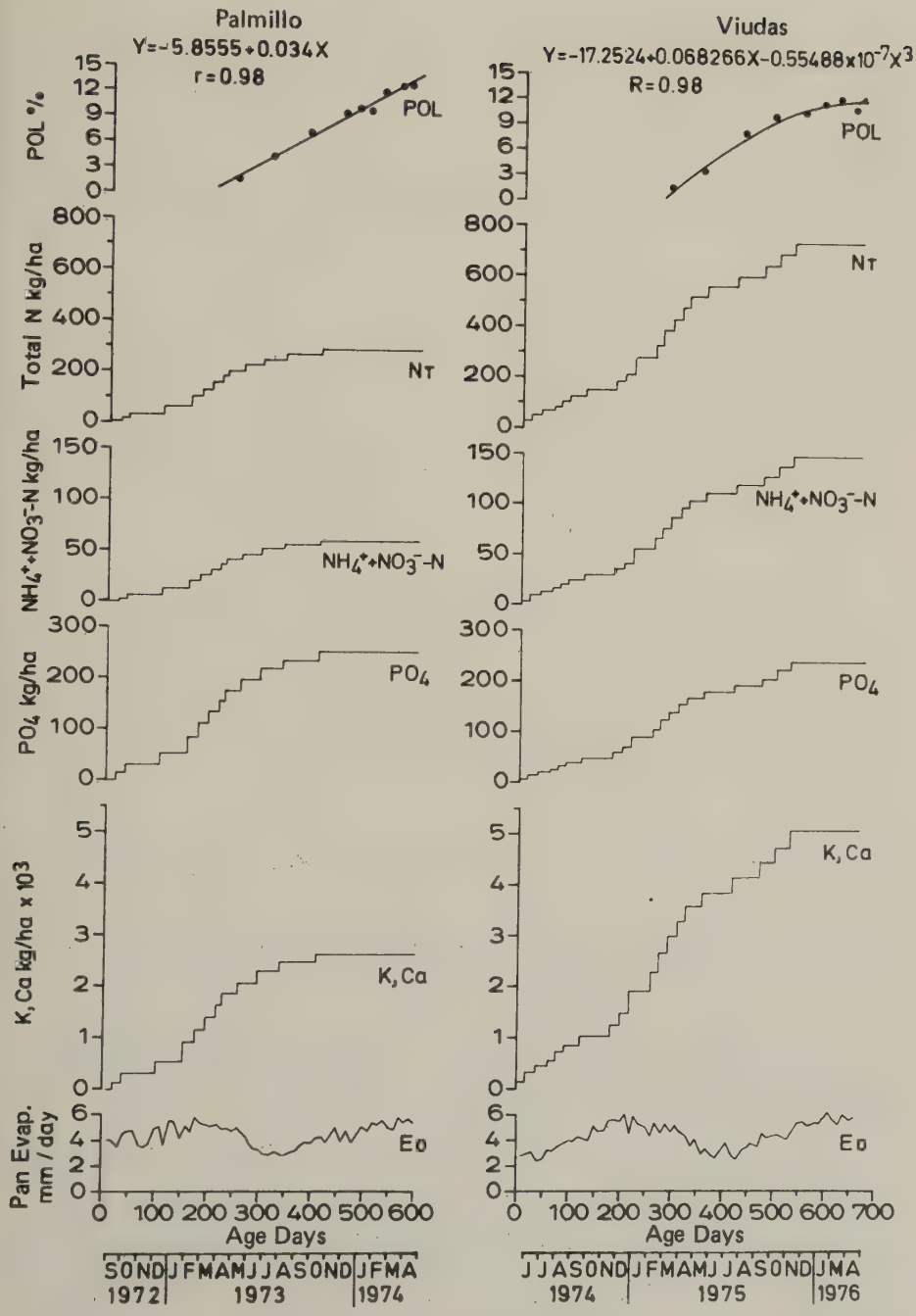

FIGURE 1. Accumulative contribution of nutrients N, P, K and Ca by filter press mud water with time. Class A pan evaporation (Eo) and pol % variation with sugarcane age.

taken at 60-90 days interval till 100 days before harvest, when they were taken at 30 days intervals to determine quality. Samples were prepared by the method of humid disintegration and pol, fiber, brix, reducing sugars and humidity were analyzed. There were no statistical differences among N rates for the quality characteristics in any age.

RESULTS AND DISCUSSION

Weather and N contribution influence of pol %

In Fig. 1, we can see the accumulative contribution in kg/ha of total N, available N ($NH_4^+ - N + NO_3^- - N$), PO_4, K and Ca by filter press mud water with time, and pol % and class A pan evaporation (Eo) variation with sugarcane age.

We have considered the pol % as the quality indicator to study influence of weather and nutrients in sugar production, because it is the best indicator of sugarcane quality; although later we will discuss the variation with age of the other quality characteristics of cane.

We can see in Fig. 1 that in Palmillo III pol increased with age linearly, and it is not affected by the Eo, or by the continuous contribution of nutrients by the irrigation water. The results are in contrast with the theories of several authors. Because of the continuous supply of nutrients even at advanced age, the cane continued to grow but still ripened normally. Likewise, 100 days after the lower Eo (colder weather) there was no increase of the pol or quality, contradictory to Valdivia *et al*[24] statement.

The results confirm Alexander[1,2] who indicated that when the ripening is induced by nutrients, climatic or water stress, if the factors return to the normal, the process of ripening continues. In our case the stress has been produced by interval between irrigations often at 30 or 40 days in which the absorption water by cane is greatly decreased, also nutrients absorption and evapotranspiration. This last factor having more influence in the induction of ripening (Valdivia *et al*[24]

It is important to indicate that stress, to induce ripening occurs in Peru long before the last irrigation (190 days before harvest) because after this date witholding water does not affect ripening.

The results of Viudas field confirm the results of Palmillo III. Ripening is slightly decreased with age.

We can also see in Fig. 1 the quantity of nutrients that are applied to the field with filter cake water, equivalent N ($NH_4^+ + NO_3^- - N$) of 60 and 145 Kg N/ha for Palmillo and Viudas, respectively.

Variation of quality characteristics with sugarcane age

In Fig. 2 we are shown the great similarity in variation of the different quality

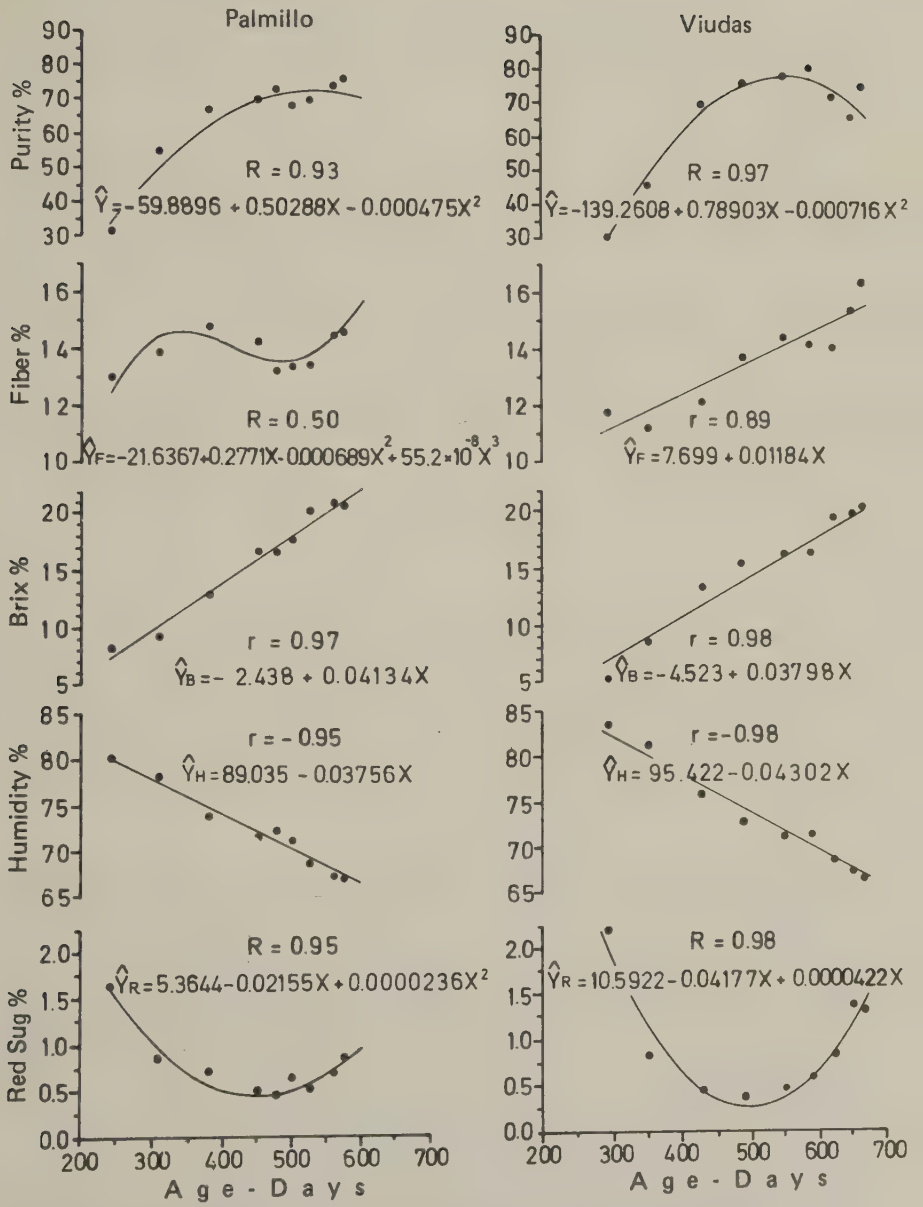

FIGURE 2. Variation of quality characteristics with sugarcane age.

characteristics with time for both fields. The only difference is for fiber where in Palmillo there's no correlation with age.

It can be seen that fiber %, brix % increase with age and that water content decreases. The purity % increases with age, but decreases after 550 days. On the contrary the reducing sugar % decreases with age, but increases after 450 to 500

days for Palmillo and Viudas respectively, this behavior show that there is a maximum ripening moment that was not observed for the pol % or for the other quality characteristics.

The maximum quality is attained later for purity % than for reducing sugars % and it is completely independent of nutrients, irrigation water and of drying off. This peak could be due to the presence of the second generation or suckers, to deterioration or to a weather influence not sufficiently large to affect the pol %. We think that it is not due to suckers because in Peru generally they appear at a lesser age (400 days); or to deterioration, because the same is not observed in Peruvian conditions with planted cane not burned because the climate is extremely arid, (without rains). Probably the maximum maturity found is a consequence of the weather, since maximum quality is approximately between 100 and 130 days after the lower Eo is obtained, confirming the statement of Valdivia

CONCLUSIONS

- The pol % increases with age linearly and it is not affected by the Eo, or by the continued supply of nutrients by the irrigation water.

- The drying – off made near harvest, with the aim of improving sugarcane ripening, did not affect cane quality.

- The behavior of the purity and the reducing sugars show that there is a maximum maturity peak (age) of cane.

- The maximum quality peak is completely independent of the supply of nutrients by the irrigation water and of drying off. This peak age is presented approximately between 100 and 130 days after the lower Eo.

- The filter cake water adds to the field a great quantity of nutrients, equivalent N (NH^+ – N + N)$_3$ – N) and 145 kg/ha for Palmillo III and Viudas fields, respectively.

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CARACTERISTICAS DE LA MADURACION DE CAMPOS REGADOS CON AQUA DE CACHAZA

Sergio V. Valdivia, Jorge C. Pinna y Herman A. Tello

RESUMEN

En la Cooperativa Casa Grande, ubicada en la costa norte del Peru, en los campos Palmillo III y Viudas, cultivados con cana H32-8560 de 4^{o} corte y planta, respectivamente, regados con agua de cachaza, se estudio las caracteristicas de maduracion de la cana. Los suelos son de origen aluvial, de textura media, calcareos, sin problemas de salinidad ni de alto nivel freatico, bien provistos de materia organica y de NPK, y tienen una alta capacidad de cambio.

Los resultados nos muestran que la pol % aumenta con la edad en forma lineal, no viendose afectada por la evaporacion tanque (Eo), ni por el aporte continuo y sostenido de nutrientes por el agua de riego,

tampoco por el hecho de dejar de regar cerca de la cosecha (agoste). Tambien que el comportamiento de la pureza y de los azucares reductores muestra en momento maximo de maduracion de la cana, completamente independiente del aporte de nutrientes por el agua de riego, y del agoste. Dicho maximo se presenta approximadamente entre 100 y 130 dias despues de la mas baja Eo.

Se encuentra igualmente, que el agua de cachaza incorpora al campo una gran cantidad de elementos nutritivos, siendo la aplicacion de N disponible de 60 y 145 kg/ha para Palmillo y Viudas, respectivamente.

ENVIRONMENT, FLOWERING, RAINFALL AND DOSAGE RATE AS FACTORS AFFECTING RESPONSE TO RIPENER POLARIS

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ABSTRACT

Increase of sucrose content following Polaris application were similar when determined by polarimetric and gas liquid chromatography analytical methods. The results showed that increases of pol % cane represented true increases of sucrose. Treatment with the ripener also lowered the levels of both glucose and fructose. Increases in sucrose content were however, influenced to a greater extent by the geographical sector of the island than by soil type. Flowered and vegetative stalks responded equally well when Polaris was applied during the flag stage of the high flowering variety S 17. Rain up to 5 mm during or just after spraying reduced response. The parameters which must be used to determine the optimum dosage for Polaris treatment are cost of Polaris and its application; its effect on sucrose content; yield after application and yield for regrowth crop.

INTRODUCTION

The ripener Polaris (N-N-bis-phosphonomethyl glycine) was shown to significantly increase the sucrose content and sugar yield in several commercial sugarcane varieties in Mauritius. It was also shown that the response to the ripener depends on the variety, the time of application, the interval between application and harvest and the dosage rate used (Julien[4,6]). More recently, spray volume and the addition of the low drift substance Nalcotrol, have been shown to have little effect on response of sugarcane to Polaris (Julien *et al*[9]).

The results reported above were based on trials in which a polarimetric method was used for the determination of sucrose content (de Saint Antoine[11]). There was a remote possibility that the increase in pol observed could have been due to some unknown dextrorotatory product resulting from Polaris application. Consequently, it was necessary to investigate whether the increase of pol was equivalent to an increase of sucrose itself.

Sugarcane is planted on a wide range of soil types under different climates in Mauritius. Eastwood[3] reported that the response of Polaris may be influenced by the environment. The data from 74 industrial trials made in 1978 using our major commercial varieties M 13/56, S 17 and M 377/56 will be used to assess

Sugarcane is planted on a wide range of soil types under different climates in Mauritius. Eastwood[3] reported that the response of Polaris may be influenced by the environment. The data from 74 industrial trials made in 1978 using our major commercial varieties M 13/56, S 17 and M 377/56 will be used to assess the effect of environment on response.

Response of the high flowering variety S 17 was shown to be lower if treatment was delayed to after anthesis. In an attempt to obtain additional information on the response of flowered stalks to Polaris, the evolution of yield and sucrose content of vegetative and flowered stalks of field of variety S 17 treated at the flag stage (a week prior to anthesis) were compared.

The effect of simulated rainfall following application of Polaris was studied in variety S 17 (Julien *et al*[8]). However, the rate of absorption of the chemical may vary with the variety. Data from trials laid down in 1978, where rain followed application, will be presented to assess the effect of rain on the response of three varieties.

A preliminary trial on variety M 377/56 indicated significant increases in sucrose content at dosage rates lower than 4 kg/ha. The data on trials laid down to obtain additional information on optimum dosage rates for that variety will be used to demonstrate some of the parameters that must be taken into account when deciding on an optimum economic dosage rate for ripener treatment.

MATERIALS AND METHODS

General

In all trials, except where indicated, the following procedures were adopted. The dosage rate of the commercial product (85% active ingredient) used was 4 kg/ha. Seventy liters of the solution was applied by a Bell 45 G Helicopter. The swath width was 18 meters covering 11 cane rows. The number of blocks ranged from a minimum of 8 to a maximum of 12, each with two treatments (control and 4 kg Polaris/ha). The experimental plots were sampled at 7 to 9 weeks after spraying unless otherwise stated. The sampling technique consisted of removing at random a sample of 15 canes from the 6th and 7th rows on the leeward side so as to reduce possible drift effects. The stalks were cut at the apex, weighed and sent for analysis of fiber % cane (de Saint Antoine and de Froberville[12]), pol % cane (de Saint Antoine[11]) and brix. From the preliminary data, the following derived variates were computed: dry matter (DM) % cane, pol % DM, fibre % DM, pol per cane, fibre per cane, DM per cane and purity.

Analysis for sucrose content

Juice extracted from 8 samples each of treated flowered, treated vegetative, control flowered and control vegetative canes of variety S 17 were analyzed by the polarimetric method given above for sucrose content. A second set of analysis for fructose, glucose and sucrose was performed on the same juice by gas liquid chromatography (Anon[1]) as modified by Mauritius Sugar Industry Research

Institute. The samples were taken 49 days after application.

Environment

In 1978, a total of 74 industrial trials were laid down as follows: 20, 33 and 21 on varieties S 17, M 13/56 and M 377/56 respectively. All the trials on variety S 17 were sprayed during the first week of May while most of those on variety M 13/56 were sprayed from May 16 to June 2. M 377/56 were sprayed from June 9 to June 20. Statistical analysis was performed on each trial. The results were pooled for each variety to study the effect of soil type, geography, altitude and rainfall on the response of each variety. The treated and control means were combined using the method of Cochran[2] which takes in consideration whether (a) the means have the same number of replications, (b) there is homogeneity of variance and (c) there is interaction.

Trials on a given variety which were sprayed outside the range of dates given above were not included in the pooled results so as to reduce the effect of differences in time of application.

Flowering and response

From two trials in the control and treated plots planted with variety S 17, separate samples of flowered stalks (at flag stage as treatment arrested elongation and emergence of inflorescence) and vegetative canes were taken for analysis at 3, 5, 7 and 9 weeks after application. An additional sample at 11 weeks was taken from Highlands.

Rainfall and response

Rain fell just after or during Polaris application in two blocks of fields. One trial each on varieties S 17, M 13/56 and M 377/56 were in the first block of fields which received four mm of rain 30 minutes after application. In the second block of fields, there was a trial on variety M 13/56 and another on M 377/56. In the middle of the spraying program, 5 mm of rain fell. Spraying had to be stopped, but it was resumed later. No rain was recorded within 24 hours after the second spraying. For these two varieties it was therefore possible to compare treated plots with and without rain.

Dosage rate and response

Two trials were laid down to study the effect of dosage rate on the response of variety M 377/56. In the first trial at Mon Desert Mon Tresor, the treatments were 0, 2, 3 and 4 kg/ha commercial product per hectare, while in the second trial at Reunion, only the control and the two highest rates were used.

RESULTS AND DISCUSSION

Analysis for sucrose content

Differences in sucrose content between treatments were of similar value for both the polarimetric and gas liquid chromatography methods (Table 1). The

hypothesis that increases in pol resulting from application of Polaris were due to some unknown dextrorotatory product, must be rejected.

In both vegetative and flowered stalks, glucose content were lower in treated stalks, confirming a decrease in the amount of reducing sugars already observed following treatment with Polaris (Julien[5]). The level of glucose in control vegetative stalks was higher than that of flowered stalks, while the level of fructose was similar. In treated canes the levels of both sucrose and glucose were similar in vegetative and flowered stalks.

TABLE 1. Sucrose, glucose and fructose in flowered and vegetative canes treated with Polaris

	Rate kg/ha	Sucrose Polarimetric g/100 ml	Sucrose GLC g/100 ml	Fructose GLC mg/100 ml	Glucose GLC mg/100 ml
Flowered	0	17.4	17.8	310	278
	4	19.7	20.3	199	174
Vegetative	0	16.1	16.9	295	340
	4	18.8	19.2	179	209
LSD P 0.05		1.3	0.7	55	47

Environment

The response of sugarcane varieties M 377/56, M 13/56 and S 17 to Polaris was significant irrespective of soil type or geographical sector.

The degree of response however, was influenced to some extent by the geographical sector, thus, response of M 377/56 and S 17 were lowest in the southern part of the Island. The best response, compared to Island average, was obtained in the North for M 377/56 and in the East for M 13/56 and S 17 (Table 2).

Response was less influenced by soil type, thus, the only difference noted was the lowest response of variety S 17 on Latosolic Brown Forest soils (Table 3).

Although lower than Island average, response of M 13/56 in the Northern Plain on irrigated and non-irrigated fields was generally good. Eastwood[3] observed poor response in a similar ecological area in Jamaica and attributed the lack of response to a long drying off period of 6 weeks. He also obtained the best responses in the wet East. He however observed no response in the central plateau. In Mauritius, good response have been obtained in the wet East but unlike Jamaica, the response was equally good on the central plateau.

TABLE 2. Increase of pol % cane following Polaris treatment in 3 varieties grown in different geographical sectors

Geographical Sector	M 377/56	M 13/56	S 17
Center	1.65 ± 0.21	–	2.04 ± 0.14
East	1.63 ± 0.72	2.33 ± 0.20	2.13 ± 0.33
North	1.99 ± 0.15	1.74 ± 0.12	–
South	1.28 ± 0.31	1.80 ± 0.25	1.18 ± 0.13
West	–	212. ± 0.35	–
Island	1.61 ± 0.16	1.95 ± 0.14	1.59 ± 0.18

TABLE 3. Increase of pol % cane following Polaris treatment in three varieties grown in three soil types

Soil Type	M 377/56	M 13/56	S 17
Latosolic Brown Forest	1.82 ± 0.64	1.72 ± 0.17	1.01 ± 0.22
Latosic Reddish Prairie	1.55 ± 0.22	1.94 ± 0.21	1.69 ± 0.40
Low Humic Latosols	1.56 ± 0.17	2.00 ± 0.12	1.39 ± 0.31
Island	1.61 ± 0.16	1.95 ± 0.14	1.59 ± 0.18

Flowering

Maximum response as shown by increases of pol % DM and sucrose per cane was observed from 5 and 7 weeks after Polaris application in flowered and vegetative canes respectively (Fig. 1). In both types of cane, response was significant but lower at 11 weeks. The observed increases in sucrose content were attributed to both an increase of DM content as well as a higher partitioning of DM in favour of sucrose in treated canes (Table 4). These results are in agreement with previous reports (Julien[5], Julien *et al*[6]). In additon these revealed that vegetative as well as stalks with a differentiated inflorescence, react similarly to Polaris treatment, except for an earlier response in flowered canes. In agreement with this study's findings, Krasilchick[10] working in Brazil, recommends treatment of high flowering varieties after the initiation of floral primordia and prior to flower emergence.

Rainfall and response

In spite of rain following application within half an hour at Mount, response of the three varieties was satisfactory. It was noted that variety S 17 gave the lowest

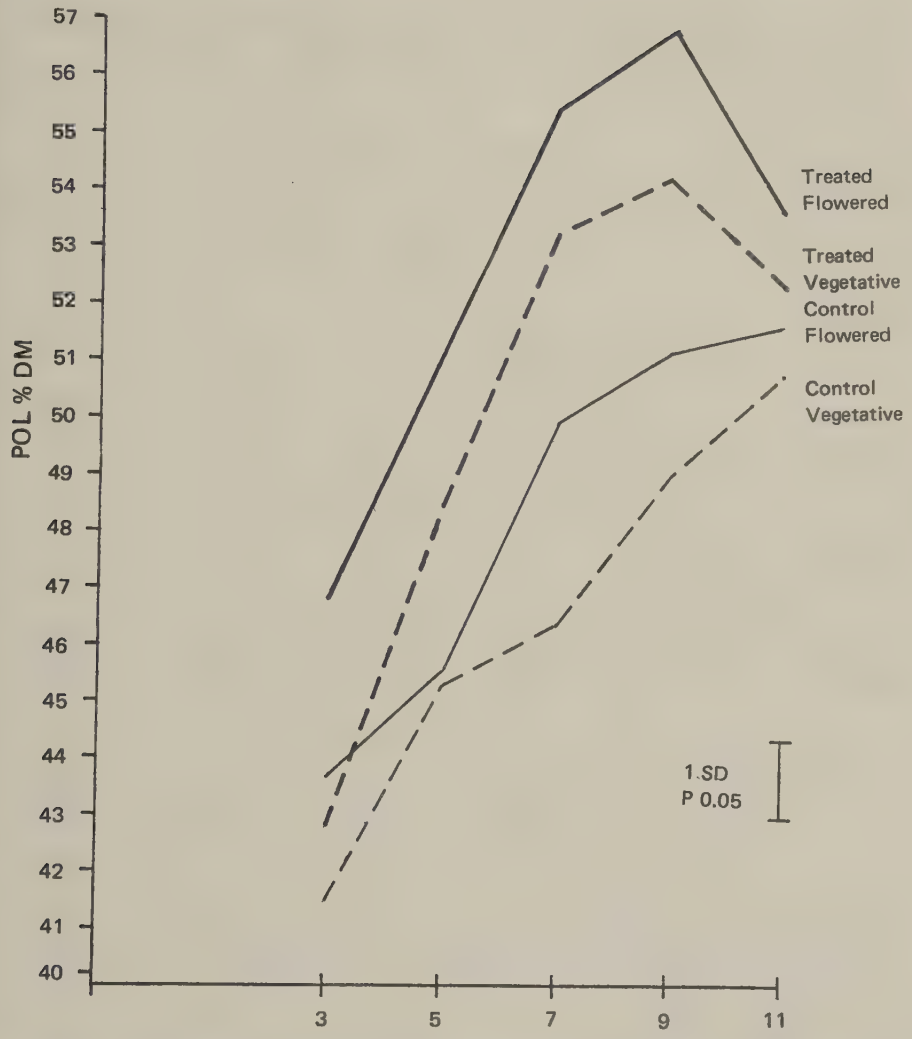

FIGURE 1. Evolution of pol % DM in vegetative and flowered canes treated with ripener Polaris.

response (pol % cane increase) while variety M 377/56 had the highest response (Table 5).

At Mon Desert Mon Tresor, response of plots having received rain was lower than those with no rain. This difference was significant for pol % cane and pol % DM in varieties M 377/56 and M 13/56 respectively (Table 6).

Results on the effect of simulated rainfall on the response of variety S 17 have indicated that 12 mm of rain within 2 hours after spraying annihilated the effect of Polaris (Julien *et al*[8]). However, in that experiment, the volume of solution used

TABLE 4. Evolution of DM % cane, fiber % DM, sugar per can in flowered and vegetative canes treated with ripener Polaris

Rate kg/ha		Weeks after application 3	5	7	9	11
				DM % Cane		
Flowered	0	21.7	22.8	24.6	25.3	27.5
	4	22.7*	23.8*	25.6*	26.1	29.0***
	0	20.2	21.4	22.9	25.7	26.8
Vegetative	4	21.9***	22.7***	24.8***	26.4	29.1***
				Fiber % DM		
Flowered	0	41.2	42.0	38.7	38.1	35.1
	4	39.0*	37.4***	34.4***	34.8***	33.6***
	0	43.6	42.2	39.5	38.7	35.8
Vegetative	4	39.7***	39.4***	35.8***	36.0**	34.8
				Sugar/Cane (g)		
Flowered	0	179	180	203	193	189
	4	192	216**	242***	244**	203
	0	129	110	110	105	90
Vegetative	4	130	121	152***	157**	132**

* *Significant at P 0.05*
** *Significant at P 0.01*
*** *Significant at P 0.001*

per hectare was considerably higher and also no nalcotrol was added. It may therefore be postulated that nalcotrol probably acts as a sticker for Polaris, and that run off with rain for low volume is less important than for high volume spray.

Response of variety M 377/56 to dosage rate

In both trials, increases of pol % cane following treatment were higher at the 4 kg/ha rate although the difference between 3 and 4 kg/ha rates (0.6 and 1.2 pol % cane at Reunion and Mon Desert Mon Tresor respectively) was not statistically significant. On the other hand, the linear component of variance for rates was highly significant while the quadratic component was not significant. Response to the 2 kg/ha rate was low, confirming earlier reports that this rate is below minimum (Table 7).

TABLE 5. Difference between treated and control for varieties S 17, M 13/56 and M 377/56 at Mount where 5 mm of rain fell 30 minutes after application

Variety	Pol of cane	Pol % DM	DM % cane	Fiber % DM	Purity
S 17	+ 0.4	+ 2.7*	− 0.7	− 0.4	+ 3.7*
M 13/56	+ 1.3*	+ 2.9*	+ 1.2*	− 2.2*	+ 1.9
M 377/56	+ 2.1***	+ 5.9***	+ 1.1*	− 5.6***	+ 3.2*

* *Significant at P 0.05*
*** *Significant at P 0.001*

TABLE 6. The effect of rainfall on response of varieties M 13/56 and M 377/56 at Mon Desert Mon Tresor

	Pol % cane		Pol % DM		Fiber % DM		DM % cane	
	M13/56	M377/56	M13/56	M377/56	M13/56	M377/56	M13/56	M377/56
Control	13.7	10.0	51.2	44.5	42.3	42.8	26.7	22.4
Treated+Rain	15.0	11.2	53.5	48.5	40.2	39.2	28.0	23.1
Treated—Rain	15.4	12.3*	55.4*	50.0	38.0*	38.8	27.9	24.7
LSD P 0.05	0.6	1.0	1.4	2.8	1.6	2.6	0.9	1.5

**Denotes significance at P 0.05 between with and without rain*

TABLE 7. Effect of dosage rate on response of variety M 377/56 to "Polaris"

Rate kg/ha	Pol % Cane		Pol % DM		Fresh Weight tons/ha		Sugar tons/ha	
	MDMT	Reunion	MDMT	Reunion	MDMT	Reunion	MDMT	Reunion
0	12.4	12.5	47.9	48.9	99.3	71.3	9.31	6.78
2	13.0	—	48.4	—	92.4	—	9.10	—
3	13.2*	13.7*	49.0	51.8	94.5	70.9	9.55	7.56*
4	14.4***	14.3**	50.4	53.5**	98.6	69.9	11.02***	7.73*
LSD P 0.05	0.8	1.2	3.3	3.3	14.6	3.7	0.54	0.78

The results of cane yield indicated a small, and insignificant reduction in yield for the 3 and 4 kg rates compared to the control (Table 7). Consequently, the increase in sucrose content will be partly offset by this reduction in yield. In both sites, although the cost of application was lower for the 3 kg/ha rate, the

gains accruing from application were higher for the 4 kg/ha rate.

The two trials were sprayed late in June when growth was slowing down, this explains the small difference in yield observed. If applications were made earlier or in environments with high growth rates, the reduction in yield must be determined so as to derive the optimum economic dosage rate. The regrowth of variety M 377/56 was not affected by Polaris however, in other varieties such as S 17 where regrowth can be delayed (Julien and Goolamhossen[7]), the effect of dosage rate on the yield of the following year must also be integrated in equation for the derivation of optimum dosage rate.

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EL MEDIO AMBIENTE, LA FLORACION, LAS LLUVIAS y LOS PORCENTAJES DE DOSAJE COMO LOS FACTORES QUE AFECTAN LAS RESPUESTAS AL MADURADOR POLARIS.

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RESUMEN

Incrementos de contenidos en sacarosa despues de la aplicacion de Polaris, fueron similares con determinados por metodos analiticos ya sean polarimetricos y cromotografia a gas liquido, mostraron que el incremento de pol % cana representa un verdadero incremento de sacarosa. Tratamientos con el madurador bajaron los niveles de glucosa y fructosa. Incrementos en el contenido de sacarosa fueron influenciados en gran parte por sector geografico de la Isla por el tipo de suelo. Los tallos en crecimiento y florecidos responden igualmente bien cuando es aplicado Polaris en la hoja bandera en la variedad de floracion alta S 17. Las lluvias de hasta 5mm durante o justamente despues de la aplicacion redujeron la respuesta pero no la anularon completamente. El efecto en el contenido de sacarosa, los rendimientos despues de la aplicacion, los rendimientos para el desbrote de cultivo, el costo del producto y de la aplicacion son parametros que deben ser integrados para determinar los dosajes optimos para el tratamiento del madurador.

RIPENER EFFICACY AS AFFECTED BY RATOON STUNT DISEASE

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ABSTRACT

Over a three-year period the efficacy of glyphosine was studied on RSD infected and non-infected plots of the variety CP 65-357. The efficacy of glyphosine was significantly greater in the non-infected plots. Although the sucrose content was increased in all treated plots, application of glyphosine resulted in a positive effect on sugar per hectare in the non-infected cane and a negative effect on sugar per hectare in the RSD infected cane.

INTRODUCTION

Initial work with the ripener glyphosine produced unacceptable frequencies of non-responsive fields in Louisiana (Legendre and Martin[4,5]). In efforts to improve ripener technology, the identification of agents or factors that would reduce the level of response were considered. It has been demonstrated that sugarcane infected with ratoon stunt disease (RSD) has higher level of sucrose than non-infected sugarcane (Forbes *et al*[2]). It was therefore hypothesized that RSD-infected sugarcane would not respond to ripener treatment as much as non-infected sugarcane. The research reported herein was undertaken to test this hypothesis.

MATERIALS AND METHODS

During the 1976-1978 harvest seasons replicated 6 meter plots of the cultivar CP 65-357 were grown at the St. Gabriel Farm of the Louisiana Agricultural Experiment Station. Plots planted with 1st progeny of heat treated (Cifuentes *et al* [1]) seed were considered disease-free. Plots planted with progeny of RSD infected seed were considered RSD-infected.

During the second week of September, glyphosine was sprayed at 3.36 kg/ha in 168 liters of solution/hectare. Six weeks after treatment all plots were sampled. Ten stalk samples were cut flush with the ground, stripped, topped through the apex, weighed, and milled once through a 3-roller mill. For each juice sample, brix was determined by hydrometer, apparent sucrose by polarization, and apparent purity as the ratio of apparent sucrose and brix (Meade and Chen[7]). From these results, the yield of recoverable sugar per ton of cane was calculated by a method previously described (Legendre and Henderson[3]). The yield of cane/ha was cal-

culated by multiplying mean stalk population/ha by mean stalk weight. Finally, the yield of recoverable sugar/ha was calculated by multiplying recoverable sugar/ton by yield of cane/ha.

The experiment was designed in a randomized complete block with a split plot arrangement of treatments. The varietal source of variation was examined on the whole plot with disease by glyphosine factorial effects observed on sub-plots.

To express the efficacy of the glyphosine treatment, in each replicate the yield component of the treated plots were expressed as percent of their respective control plots.

RESULTS AND DISCUSSION

The effects of RSD on the yield components studied are presented in Table 1. The infected plots had significantly higher sucrose, purity and sugar per ton than non-infected plots. Although not statistically significant, the RSD infected plots also had lower stalk weight and sugar per hectare than the non-infected plots. These results are in accordance with previously reported effects of RSD (Forbes *et al*[2]).

TABLE 1. Effect of RSD on yield components of CP 65-357.

Yield component	RSD free	RSD infected
Sucrose*	15.7%	16.4%
Purity*	78.7%	80.0%
Sugar/Ton*	90 kg/ton	95 kg/ton
Stalk Weight	1.14 kg	1.06 kg
Sugar/Hectare	9533 kg/ha	9287 kg/ha

* *Statistically significant at the 0.5% level of probability.*

As seen in Table 2, the efficacy of glyphosine was greater in the non-infected plots than in the infected plots. The values of sucrose, purity and sugar per ton for the treated plots were not different for infected and non-infected plots. Thus the reduced efficacy in infected plots may be associated with the higher initial values of sucrose, purity, and sugar per ton associated with the incidence of the disease.

As reported earlier (Martin *et al*[6]) glyphosine affects the growth rate of sugarcane and therefore, can affect stalk weight, and tonnage. As also seen in Table 2 glyphosine had a greater effect on stalk weight in the RSD infected plots than in the non-infected plots, although not statistically significant.

Integration of all yield components revealed that the presence of RSD significantly altered the effects of glyphosine on sugar per hectare. Glypohosine treatment increased the sugar per hectare of non-infected plots by an average of 4.37%. The same treatment resulted in a 6.41% reduction in sugar per hectare in the RSD infected plots.

TABLE 2. The effect of RSD on the percent change in yield components as a results of glyphosine application.

Yield component	RSD free	RSD infected
Sucrose*	11.56	6.74
Purity*	3.12	0.95
Sugar/ton*	13.51	7.20
Stalk weight	−7.52	−12.30
Sugar/hectare	4.37	−6.41

* *Statistically significant at the 0.5% level of probability.*

These results help explained some of the inconsistencies originally experienced with glyphosine. Indeed the efficacy of the ripener is negated by the presence of RSD. It is worth emphasizing that while there was no significant difference in the yield of sugar per hectare between the infected and non-infected untreated plots, the application of glyphosine resulted in a positive effect on the non-infected cane and a negative affect on the RSD-infected cane.

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LA EFICACIA DEL MADURADOR AFECTADA POR LA ENFERMEDAD DEL ACHAPARRAMIENTO.

F. A. Martin, R. J. Steib and G. M. Dill

RESUMEN

En un periodo de tres años fue estudiado la eficacia del glyphosine en ensayos de la variedad CP 65-357 infectada y no infectada con R.S.D.

La eficacia de glyphosine fue significativamente mas grande en los ensayos no infectados.

Aunque el contenido de sacarosa se incremento´ en todos los ensayos tratados, la aplicacion de glyphosine resulto´ en un efecto positivo en azucar por hectarea en caña no infectada y efecto negativo en azucar por hectarea en caña infectada con R.S.D.

EFFECTS OF RIPENERS ON SUGAR QUALITY IN CULTIVAR H50-2036

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ABSTRACT

In the lower part of the Chicama Valley (northern coast of Peru), a study was conducted to know the effect of Ethrel 2 1/ha + 15 kg of urea/ha, Tween-20 10 1/ha, and Polaris 4.2 kg/ha on the quality of cultivar H50-2036. These substances were applied to sugarcane that were 20-months old, or at 64 day-old sugarcane before harvesting. The randomized complete block design which included a control was used in the study. The plots were located in an area of 0.72 ha.

Variations in quality (fiber, pol, brix, reducing sugar, purity and recoverable sugar) over time, in treatments and between them, were evaluated 9 times prior to the application of ripeners until the canes were harvested. The yield of cane and sugar was also evaluated.

The results showed that there was no significant difference for the percentage of pol and recoverable sugar between initial and final values, in sugarcane treated with Ethrel and Tween-20 and the one obtained from the control. Sugar cane treated with Polaris, however, did show a significant variation in this respect. At the moment of harvesting, the percentage of pol, recoverable sugar, cane/ha and sugar/ha in the sugarcanes treated with the ripeners were not significantly different from the one obtained from the control.

INTRODUCTION

The use of chemical substances as regulators of sugarcane growth in order to help its ripening is intensively being studied in all sugarcane areas in the world, especially in these areas where such climatic factors as temperature and precipitation do not allow these plants to ripen adequately. For example, in rainy areas, the sucrose average during those periods are kept with the application of phytoregulators when the least for sugarcane harvesting is not, e.g. appropriate at the beginning or at the end of this harvesting period.

Specifically regulators of plant growth affect ripening either directly by interrupting plant growth or indirectly by blocking the enzymes that control the storage of sucrose in the cane. The enzymes can delay or block the transformation of

sucrose into the reducing sugar that the plant uses as a source of energy for keeping on growing so that ripening is hastened (Humbert[5]). The idea that plant quality increases by preventing the plant from growing is an old one. Now there is another theory about this and it has been proved by other scientists, especially by Alexander[1,2], who thinks that increase of sugarcane quality is due to biochemical modifications that take place when the plant is suffering from "stress", which can be caused by cold temperature (not extremely cold), by decrease of water supply or by shortage of nutritive substances.

In our valleys with sugarcane plantations, where temperature changes very little and there is almost no precipitation (situation that allows to harvest during all year), the effect of chemical ripeners should be easily noticeable. In practice, however, it is not like that. It seems that this is due to the fact that ripening is induced continually by the waterings that are made at regular intervals of time. It can be noticed that the percentage of sucrose in those canes which are going to be harvested soon is above 11% of the least appropriate times.

In Peru, there are very few investigations carried out with chemical ripeners. Tello[11], in his trial carried out with 4 doses of Ethrel, did not find any significant difference in terms of sugarcane quality between canes with treatment and canes from the control during the 10 weeks after the application of the substance.

Now, in all those places where sugarcane is grown, researchers are trying to get a reliable chemical substance that can facilitate ripening. For this reasons, many chemical substances have been tested in different parts of the world, but even under optimal circumstances they have shown contradictory results (Alexander[1], Rugai and Gentil[9]). These experiments show that the results obtained vary considerably not only because of the characteristics of the substance itself but also because of variety, climatic and cultivate conditions, existing in different sugarcane areas of the world. This can be seen, for example, in the trials performed by Yates[13], who tested different substances in experiments carried out in field trials and in screening trials. One of these substances is Ethrel and this scientist obtained negative results in the first type of experiment and positive results in screening trials.

In the same way, Hinojo *et al*[4] tested different substances in ecological areas of Tucuman and Juju in Argentina, and they obtained the following results: there is a possibility that Ethrel 24, RH715, Racuza 50 and Polaris can be used with positive results in both ecological areas. With these substances, the best results were obtained in the area of Tucuman in cultivar of sugar cane treated with small quantities of Na-56-62 and Na-56-79. On the other hand, in the area of Juju the best results were obtained with Racuza 50 and Polaris used in moderate and large quantities. However, the results obtained with Ethrel were similar in both areas.

Rostron[8] also tested Ethrel and Polaris in cultivar NCO-310, which was being watered, and he discovered that sugarcane quality increased from the 4th or 6th week until the 12th week after the application of the substances. The scientist reports that Ethrel was more effective than Polaris at the same level of application, that both substances caused symptoms of water deficiency in plants; and he

also says that the negative effects of Ethrel in some cultivars of sugar cane could be due to the fact that these are more sensible to this chemical substances than to NCO-310.

Other examples showing that the results obtained vary according to the place are the trials carried out with Polaris by Selleck *et al*[10] in Florida, Hawaii and Louisiana during the Autumn of 1972 and the Spring of 1973. They got a sucrose increment (in tons) of 10% in Florida and Louisiana and of 2.6% – 12% in Hawaii. In the same way, Zskhochie[14] by using Polaris in Hawaii obtained results varying from excellent to poor.

In general, literature about this matter shows that the best results were obtained in rainy areas, where chemical substances were used at the beginning or at the end of sugarcane harvesting, that is to say, when the percentage of pol in the areas is significantly below average, a situation that never happens in the Peruvian valleys where sugar cane is raised. As a matter of fact, Pan and Lee[6] and Redman[7] discovered that by using Polaris, the best results are obtained when natural conditions do not favor ripening. This idea is generalized by Selleck *et al*[10] when they say that in their trials with Polaris this substance was able to facilitate ripening under a wide variety of climatic and cultural conditions.

In this kind of experiments, it seems that the age of the plant and the percentage of sucrose at the moment of application of the substance are two factors that should be taken into consideration. With respect to this, Hinojo *et al*[4] report that the application of Polaris to sugar plants that have less than 6% of sucrose could bear unsatisfactory results. On the other hand, Pan and Lee[6] obtained positive results by using Polaris with sugarcanes that were 12 months, when harvesting took place 8 weeks after applying a dose of 4.48 kg/ha.

It is necessary to keep on studying the use of chemical substances as ripeners for there are many sugarcane areas in the world where production could vary significantly if these substances were introduced successfully in their cultivation systems. Vlitos[12] besides insisting on doing more research in this direction, emphasizes the importance of physiology of plants as has in connection with the use of chemical ripeners. On the other hand, Fauconnier and Bassereau[3] sum up the importance of this task as follows: "In spite of isolated minor successes it can be said that this quite strange technique is not completely developed yet."

It is therefore, the objective of this work to determine the effect of the application of Ethrel, Tween-20 and Polaris on sugarcane quality, on the basis of the experiments performed in cultivar H50-2036, located in the lower part of the Chicama Valley.

MATERIALS AND METHODS

The experiment was set up in plots of land number 2, 4, 6, and 8, located in the field called Nazareno belonging to the Agricultural Cooperative Cartavio.

In these plots first-cut cultivar H50-2036 were planted. The field was watered for 15.4 months and harvesting took place when plants were 22.1 months; the field received 19 waterings of 1299 m^3/ha per each watering and 230 kg N/ha in two doses (the first one after one month and the second one after 5 months). The chemical substances were applied by plane at 64 days (9 weeks) prior to harvest.

The experimental plots were of 0.72 ha each and the treatments were distributed in a randomized complete block design with 4 replicates. The four plots in a block were adequately separated (9 m or 6 furrow). The blocks were constructed separately too (120 m around). The used doses were: Ethrel = 2 1/ha + 15 kg of urea/ha, Tween-20 = 10 1/ha, and Polaris = 4.2 kg/ha.

Control of sugarcane quality began with a sampling taken before the application of the substances to estimate the initial state of the quality; then a sampling was taken each week until harvesting and finally, a sampling with burnt sugar cane (Production Control). From each plot of land, 9 samplings were taken (36 per treatment, per evaluation) which were analyzed separately. Quality analysis has determined the following quality variables: fiber, pol, brix, reducing sugar, purity, humidity and recoverable sugar of 96°. To determine the last variable the following formula was used:

% AZRE = (pol − 0.046 fiber) (1.603 − 59.536/Pur. C. J.) 1.041, where:
Pur. C. J. = purity of clarified juice

Since the experimental design used was that of blocks at random and that 10 periodical evaluations were performed (including the evaluation immediately before the treatments), the mathematical model for variation analysis was the following:

$$Y_{ikj} = \mu + \beta_i + \epsilon_k + P_{ik} + T_{j(k)} + e_{ijk} \quad \text{Model I,}$$

where:

- Y_{ikj} represents a variable measured at the kth evaluation of the plot under treatment j in block i ($k = \overline{1,10}$; $i = \overline{1,4}$; $j = \overline{1,4}$)
- β_i represents the actual average effect of block i; $i = \overline{1,4}$
- ϵ_k represents the actual effect of evaluation k; $k = \overline{1,4}$
- Pik represents the error of the whole plot (block per evaluation interaction)
- $T_{j(k)}$ represents the actual average effect of jth treatment within kth evaluation
- e_{ijk} represents the experimental error on measurement error regarding Y_{ijk}

Considering that it is important to know whether the variation induced by the treatment is different from the variation in the control during the evaluations, a second variation analysis on the basis of a mathematical model was made. This model is connected with the nature of the experimental administration inspite of the fact that by its nature it is a different model. This new model is:

$$Y_{ijk} = \mu + \beta_1 + T_j + \epsilon_{ij} + \eta_{k(j)} + e'_{ijk} \quad \text{Model II,}$$

where:

ϵ_{ij} represents the error of the whole plot of land (block per treatment interaction)

$\eta_{k(j)}$ represents the actual average effect at the kth evaluation within the jth treatment

e'_{ijk} represents the experimental error or measurement error of Y_{ijk}

In short, by using model I the variation of the treatment in each evaluation is measured, whereas, model II analyze the variation of each treatment throughout the evaluations. The structure of variation analysis on the basis of each model is:

Model I

(1) S.V.	(2) D.F.
Repetition	3
Evaluation	9
Error PI	27
Treat. (E0)	3
Treat. (E1)	3
Treat. (E2)	3
Treat. (E3)	3
Treat. (E4)	3
Treat. (E5)	3
Treat. (E6)	3
Treat. (E7)	3
Treat. (E8)	3
Treat. (E9)	3
Error SP	90
Total	159

Model II

(1) S.V.	(2) D.F.
Repetition	3
Treatment	3
Error PI	9
Evaluation (T0)	9
Evaluation (T1)	9
Evaluation (T2)	9
Evaluation (T3)	9
Error SP	108
Total	159

(1) Source of variation

(2) Degree of freedom

As we can see, the statistical analysis shows how meaningful the possible differences were between treatments for each of the 9 evaluations after applying the treatments (dates of samplings). It also shows how meaningful the possible induced variation was for each treatment throughout the evaluation period.

RESULTS AND DISCUSSION

After statistically analyzing the quality variables in each of the samplings and the final outcome in terms of t-cane/ha and t-sugar/ha, the following results were obtained:

Percentage of pol in cane (Table 1, Fig. 1)

Treatments with Ethrel and Tween-20, as well as the control did not show meaningful variations during the evaluation period. This means that the percentage of pol in sugarcane was not modified significantly considering the initial value of this component before the application of the treatments. However, treatments with Polaris did show a very significant variation of pol considering the initial value of this sugarcane component. This variation was from 12.62 immediately before applying the treatment to 14.29 at the moment of harvesting.

Until the sampling before the last was taken there were no significant differences either among treatments or between these and the control. If we consider only the highly significant difference between the treatments and the control on the basis of the two last samplings, we can come to the conclusion that the treatment with Polaris produced the highest percentage of pol in sugarcanes (14.29), but this value is not significantly different from the one obtained in the control (13.81). However, this value obtained with Polaris is highly significant compared to the one obtained with Ethrel (12.80) and only signifiant compared to the one obtained with Tween-20 (13.30).

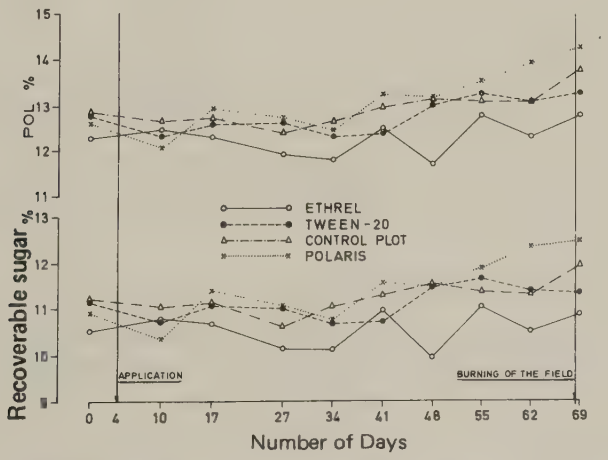

FIGURE 1. Percentage variation of Pol and recoverable sugar over the time after applying treatments

Percentage of Recoverable sugar of 96° (Table 2, Fig. 1)

Similarly, as what was observed with the percentage of pol, the treatment with Polaris significantly increased the percentage of recoverable sugar of 96° during the evaluation period, for the initial value before the treatment was applied was 10.94 and it was 12.50 at the moment of harvesting (64 days after applying the substance). In the same way, at the moment of harvesting the percentage of recoverable sugar obtained with Polaris (12.50) was not significantly different from the percentage obtained in the control (11.97), but the former value is significant

TABLE 1. Average percentage of Pol in sugar cane per evaluation and treatment

Evaluations (Samplings)	Treatments				Significance	M. S. D.	
	Ethrel	Tween-20	Polaris	Control Plot		.95	.99
0 days(1)	12.28	12.81	12.62	12.87	NO	0.873	1.140
10 "	12.48	12.34	12.08	12.68	NO	0.873	1.140
17 "	12.32	12.60	12.94	12.75	NO	0.873	1.140
27 "	11.94	12.65	12.76	12.42	NO	0.873	1.140
34 "	11.82	12.34	12.46	12.67	NO	0.873	1.140
41 "	12.51	12.39	13.25	12.98	NO	0.873	1.140
48 "	11.73	13.06	13.21	13.18	xx	0.873	1.140
55 "	12.79	13.28	13.56	13.13	NO	0.873	1.140
62 "	12.33	13.13	13.96	13.10	xx	0.873	1.140
69 "	12.80	13.30	14.29	13.81	xx	0.873	1.140
Significance	NS	NS	xx	NS			
M.S.D.(2) .95	0.948	0.948	0.948	0.948			
M.S.D. .99	1.238	1.238	1.238	1.238			

(1) Immediately before applying the treatments
(2) M.S.D. = Minimal significant difference
xx Significance at 0.01 level of probability

compared to the ones obtained with Ethrel (10.88) and Tween-20 (11.14).

Percentages of Purity and Reducing Sugar (Fig. 2)

These characteristics of sugar cane quality showed no significant variation over time, neither among average treatments, nor among treatment at a certain period.

Percentage of Brix (Fig. 3)

Although brix, both in the control in the treatments showed a meaningful increase throughout the evaluation period, this increase has the same quantity in each of the treatments until the 8th sampling, and from this moment on the increase caused by Polaris further increased whereas the one caused by Ethrel decreased.

Percentages of Humidity and Fiber (Fig. 3)

In terms of humidity, the treatments showed a highly significant decrease and the control plot of land showed only a significant decrease throughout the evaluation period. In terms of fiber, the treatment with Ethrel showed a significant decrease which accords with the variation in humidity. The other treatments did not show any variation in fiber.

TABLE 2. Average percentage of recoverable sugar (96°) per evaluation and treatment

Evaluations (Samplings)	Treatments				Significance	M. S. D.	
	Ethrel	Tween-20	Polaris	Control Plot		0.95	0.99
0 days(1)	10.55	11.19	10.94	11.28	NS	1.03	1.34
10 "	10.81	10.74	10.37	11.07	NS	1.03	1.34
17 "	10.70	11.12	11.42	11.19	NS	1.03	1.34
27 "	10.15	11.04	11.09	10.64	NS	1.03	1.34
34 ..	10.12	10.70	10.76	11.08	NS	1.03	1.34
41 "	10.98	10.74	11.59	11.33	NS	1.03	1.34
48 "	9.95	11.49	11.51	11.56	xx	1.03	1.34
55 "	11.08	11.67	11.90	11.40	NS	1.03	1.34
62 ..	10.51	11.40	12.37	11.34	xx	1.03	1.34
69 "	10.88	11.36	12.50	11.97	x	1.03	1.34
Significance	NS	NS	x	NS			
M.S.D(2) 0.95	0.948	0.948	0.948	0.948			
M.S.D. 099	1.238	1.238	1.238	1.238			

(1) Immediately before applying the treatments
(2) M.S.D. = Minimal significant difference
x Significance at 0.05 level of probability
xx Significance at 0.01 level of probability

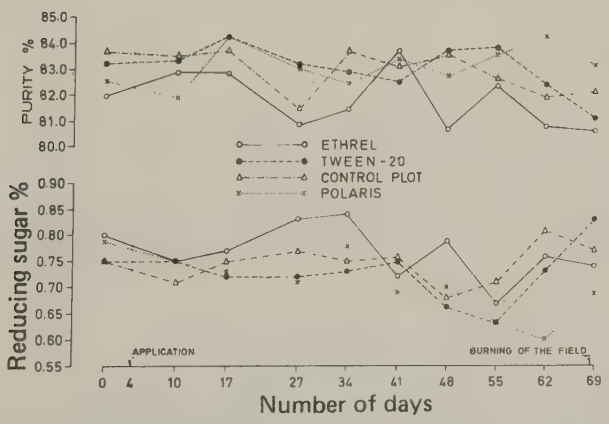

FIGURE 2. Percentage variation of purity and reducing sugar over time after applying the treatments

Among the treatments, significant differences regarding the two variables were observed from the 4th evaluation until harvesting, except fiber at the time of harvesting. This is due to the fact that, although the change of these variables

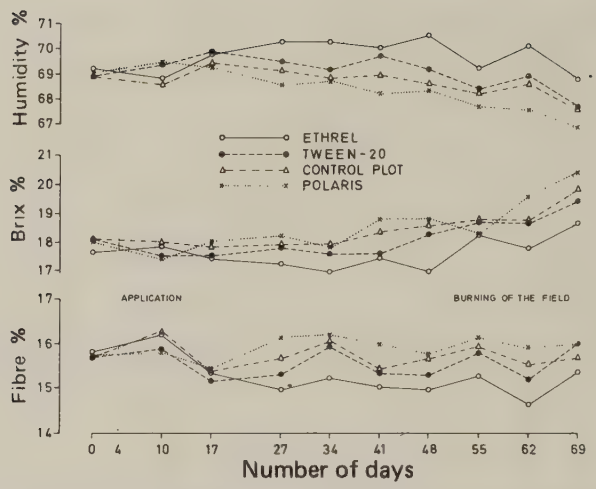

FIGURE 3. Percentage variation of humidity, Brix and Fibre over time after applying the treatments

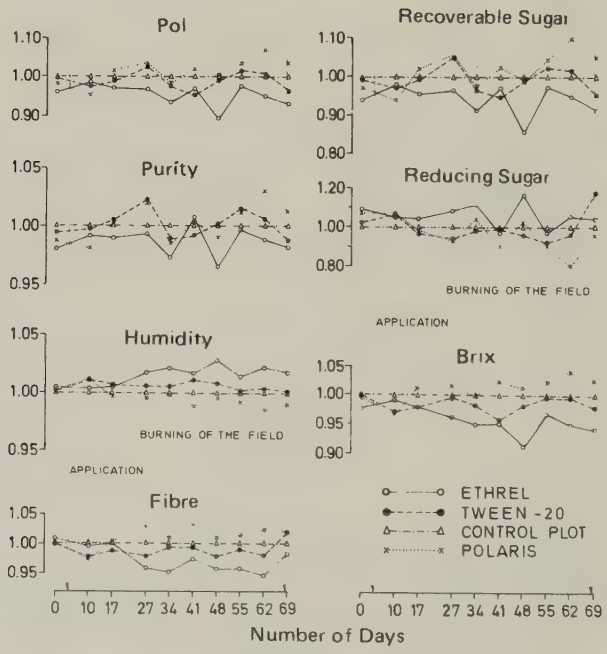

FIGURE 4. Relative variation of quality over time after applying the treatments

is inversely proportional (this was determined in the laboratory), their variation quantity is not the same.

In Figure 4, we can observe the quality variation of each treatment, compared to the variation in the control which has the unitary value. we can see that

TABLE 3. Yield of the treatments at harvesting

	Ethrel	*Tween-20*	*Polaris*	*Control plot*
t-cane/ha	310.9300	301.7200	280.4300	285.0600
t-recoverable sugar/ha	33.7714	34.1216	35.1014	34.1437

in every quality variable. Tween-20 is closer to the control, Polaris is slightly positive and Ethrel slightly negative.

Yield

We did not get any significant variations in the yield t-cane/ha nor t-recoverable sugar/ha, as shown in Table 3.

CONCLUSIONS

In the treatments with Ethrel, Tween-20 and in the control, the percentage of pol and recoverable sugar was not significantly modified considering their initial value (before the application of the substances). The trial with Polaris did show a significant increase.

In connection with the same variables, at the time of harvesting, there was no significant differences between the treatments and the control.

There was no significant difference among the treatments in yield t-cane/ha, nor t-sugar/ha.

In comparison with the control, the general quality of the treatment with Tween-20 evolved in the same way as in the control, the quality of the treatment with Polaris was slightly positive and the quality of the treatment with Ethrel was slightly negative. Both treatments, however, did not show a significant result as compared to the control.

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EFECTO DE LOS MADURADORES EN LA CALIDAD DEL CULTIVAR DE CAÑA H50-2036

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RESUMEN

Se realizo un estudio en la parte baja del Valle Chicama (costa norte peruana) en el cultivar de caña H50-2036 para conocer el efecto

de: Ethrel 2 l/ha + 15 kg de urea/ha, Tween-20 a 10 l/ha y Polaris a 4.2 kg/ha. Se aplico en caña de 20 meses de edad, 64 dias antes de la cosecha, utilizando un diseño de bloques completamente al azar con parcelas de 0.72 ha. Se evaluo la variacion de la calidad (Fibra, Pol, Brix, Reductores, Pureza y Azúcar Recuperable), a traveś del tiempo desde antes de la aplicacíon hasta la cosecha y entre tratamientos en cada una de las 9 evaluaciones, asi como los rendimientos en caña y azúcar en la cosecha. Los resultados indican que en los tratamientos Ethrel, Tween-20 y Testigo, los % de Pol y Azucar Recuperable, no variaron significativamente respecto a su valor inicial, variacion que si fue significativa en Polaris. En el % de Pol, % azucar recuperable, t-caña/ha y t-azúcar/ha, al momento de la cosecha no se observaron diferencias significativas entre los tratamientos respecto al testigo.

A REVIEW OF SUCROSE ENHANCER TRIALS IN JAMAICA IN 1974-78

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ABSTRACT

The effect of Polaris, Mon 8000, Embark, Asulox and LFA 2129 on the juice purity and sucrose content of several sugarcane varieties in Jamaica during 1974 to 1978 was discussed. Fields sprayed with Polaris in the high rainfall area had, on the average, 4% higher purity and 7% higher pol % cane than untreated fields with maximum increases occurring 6 to 7 weeks after application. Fields in the irrigated areas did not respond to Polaris. Mon 8000 showed definite sucrose enhancing ability in both the irrigated and high rainfall areas, producing 11.00 and 15.00% higher pol % cane in both areas respectively. Compared with Polaris and Mon 8000, Embark, Asulox and LFA 2129 produced little or no increases in the pol % cane of the varieties tested. Testing of these 3 products was discontinued at the end of the 1978 crop. Polaris is being used commercially and trials with Mon 8000 are continuing.

INTRODUCTION

The use of chemicals to promote or maintain the sucrose content and purity of sugarcane is being investigated in many sugarcane growing areas of the world. The need for such treatments is justified by the occurrence of conditions at harvest, primarily high temperatures and high rainfall, which favor vegetative growth rather than sucrose accumulation (Lengendre *et al*[10], Azzi *et al*[1]). The potential for sucrose enhancers in Jamaica has been reported by Eastwood[4,5,6].

In Jamaica, cane is grown on a 12-month cycle in 6 fairly distinct ecological areas of the island, namely, the Central Highlands, Wet West, Dry North Coast. Wet East, Wet North Coast, and the Irrigated Plains. Of these, the latter 3 would be more likely to benefit from the application of sucrose enhancers.

The cane harvest generally begins in December and ends in the late July. Juice quality increases from December to mid-April and declines thereafter. As elsewhere (Clowes[3], Kumar *et al*[9], Julien[8]), sucrose enhancer applications in the incline or decline periods are more likely to be beneficial than in the maximum

TABLE 1. Chemicals tested in stage 1 sucrose enhancer trials during the period 1972-1978

Trade Name/Code Number	Manufacturer	Sucrose enhancing activity in Jamica	Remarks
Racuza	Velsicol	Low	Testing discontinued
Pesco 1815	Fisons	Low	Testing discontinued
E 8728	Chemagro	None	Testing discontinued
M 2526	May and Baker	Good	Testing discontinued due to high mammalian toxicity
GS 241	Pfizer	Moderate to low	Testing discontinued
WL 17731	Shell	Moderate to low	Testing discontinued
Ethrel	Amchem	Inconsistent	Testing discontinued in favor of Polaris
Polaris	Monsanto	Good in non-irrigated areas	Advanced through to commercial utilization
LFA 2129	May and Baker	Fair though inconsistent	Advanced to Stage 2
Asulox	May and Baker	Fair though inconsistent	Advanced to Stage 2
Embark	3M	Fair though inconsistent	Advanced to Stage 2
Mon 8000	Monsanto	Consistently good	Advanced to Stage 2
Off Shoot – T	Procter and Gamble	None	Testing discontinued
Activol (GA_3)	ICI	None	Testing as a ripener discontinued
Bfn 7815	Boots	Fair	Repeated testing in Stage 1 (1979)

juice quality period from April to mid-May.

A 3-stage sucrose enhancer testing program was initiated in 1972. The first stage consisted of the preliminary screening of chemicals, using replicated small plots (60 m^2); the second of field evaluation, using replicated strips (0.4 – 0.8 ha); and the third, of semi-commercial evaluation involving several fields in a block. Stage 1 and Stage 2 trials were conducted in the early and late crop periods in the 3 major ecological areas, the Wet East, the Wet West and the Irrigated area. Stage 3 trials were conducted only in those areas that in earlier stages showed promise of giving economic response.

To date, only Polaris passed all 3 stages to commercial usage. Other chemicals tested in Stage 2 were LFA 2129 and Asulox (May and Baker), Embark (3M) and Mon 8000 (Monsanto). The chemicals tested in Stage 1, together with their performances are listed in Table 1. This paper summarizes the results of the Stage 2 trials conducted with Polaris, LFA 2129, Asulox, Embark and Mon 8000 during the period 1974 through 1978.

Of these 5 chemicals, the activity of Polaris (N, N bis-phosphonomethyl glycine, Monsanto Co.) was by far the most documented. Investigations (Azzi *et al*[1], Eastwood[5], Buren[2], Julien[8], Selleck *et al*[13] and others) have shown that it was effective in improving the juice quality and sucrose content of sugarcane.

With regard to Mon 8000 (sodium salt formulation of glyphosate, N-phosphonomethyl glycine), studies conducted in Hawaii (Teshima *et al*[14], Hilton *et al*[7]), in Jamaica (Eastwood[4]), and elsewhere, indicated that it was superior to Polaris. Mon 8000 was also found to be superior to Embark (N-2, 4 dimethyl-5-trifluromethyl, sulfonyl, amino, phenyl, acetamide) and Ethrel (2-chloro-ethyl phosphoric acid) in South Africa, producing significant, sucrose increases in both the mature and the immature sections of the sugarcane stalks (Clowes[3]).

While Embark produced some ripening activity in immature sugarcane under South African conditions, it was not as effective as Ethrel when applied to mature sugarcane (Clowes[3]). Embark was also compared with Mon 8000, Polaris, and Ethrel in Hawaii. While the latter 3 resulted in substantial sucrose increases, no increase were attributed to Embark (Teshima *et al*[14]).

Although there have been trials with Asulox (Methyl 4-aminobenze-nesulphonyl, carbamate) as a sucrose enhancer, no reporters could be found in the literature regarding the sucrose enhancing activity of this and the other May and Baker Co. product LFA 2129.

EXPERIMENTAL PROCEDURE

Stage 2 trials comparing Polaris (3.5 - 4 kg/ha) with untreated controls

were conducted during the early and late crop periods of 1974 and 1975. During 1976 and 1977, these trials also included Embark (1 kg a.i./ha) LFA 2129 (4 kg a.i./ha) and Asulox (4 kg a.i./ha). Trials during 1978 concentrated on Mon 8000 (0.5 kg a.i./ha). Approximately 55 Stage 2 trials with the major varieties in the 3 main ecological areas were conducted during 1974-78.

In these trials, the treated area consisted of strips 16 – 24 rows wide running the lengths of the field (approximately 0.4 – 0.8 ha) and separated by adequate discard area. Chemicals were applied in 10-15 l water/ha by a fixed wing aircraft to canes 10-11 months old. Four 10-stalk samples were collected from each strip 2 weeks prior to, at spraying, and at fortnightly intervals thereafter to harvest, approximately 6 – 8 weeks after spray.

At harvest, strips were burnt and reaped according to normal Jamaican field practice. At the mill, the first expressed juice was analyzed for brix and pol % juice. From these, purity and pol % cane were calculated.

Additional data on the effect of chemicals on cane tonnage and ratoon regrowth were also collected from most trials. These results have been reported previously (Eastwood[5]).

RESULTS

Physiognomic effects of the various chemicals were generally visible 3 - 4 weeks after spray. Leaves of Polaris treated canes usually exhibited tip burn and margin scorching, together with a general chlorosis of the leaf tip. Mon 8000 treated canes allowed similar symptoms 4 weeks after spray. These were usually followed by drying out and constriction of the spindle, necrosis of the meristem, reduction of joint lengths and bulging of the young internodes, and side shooting (Fig. 1). LFA 2129 produced large chlorotic patches on leaves with some tip burn (Fig. 2), while Embark produced smaller chlorotic spots which soon turned brown. Margin and tip turn were also common.

The effects of the chemicals on juice purity and pol % cane are summarized in Tables 2 - 6. For clarity, the trials conducted in the high rainfall areas of the Wet East and Wet West ecological areas of the island were grouped together and compared with those in the irrigated area. Fields treated with Polaris in the high rainfall area had an overall 4% higher purity and 7% higher pol % cane than the untreated controls. In the Irrigated area, on the other hand, Polaris showed a consistent lack of activity resulting in a nonsignificant overall increases in pol % cane of 2% (Table 2).

LFA 2129 showed some ripening activity in the late crop period in both the irrigated and non irrigated areas, resulting in an average 5% increase in pol % cane of UCW5466 and HJ5741 (Table 3) compared with 7% with Polaris under similar

FIGURE 1. Shortening and bulging of young joints and side shooting following Mon 8000

FIGURE 2. Chlorotic patches following LFA 2129 application.

conditions. Unlike Polaris, however, sucrose increases not and obtained from LFA 2129 treated canes in the early and mid-crop periods. Neither Asulox nor Embark produced any significant ripening activity in the irrigated and non irrigated areas (Tables 4 and 5).

In contrast, Mon 8000 produced substantial sucrose enhancement in the 2 trials conducted in the high rainfall area. Pol % cane also increased in 3 of the 5 trials in the irrgated area. Juice purities in these tests were, however, not significantly improved (Table 6).

The changes in the pol % cane content of the 3 most frequently tested varieties, HJ5741, B51129 and UCW5465, relative to untreated controls are illustrated in Fig. 3. Quite apparent is the general lack of response by all 3 varieties to LFA 2129, Asulox and Embark. B51129 was the most responsive to the other 2 chemicals, Mon 8000 and Polaris. However, this is a relatively minor variety, occupying approximately 8% of the total cane acreage and virtually restricted to the eastern and central areas of the island. UCW5465 responded moderately to Mon 8000 treatment in both the irrigated and the high rainfall areas. It, however, responded poorly to Polaris. While HJ5741 was moderately responsive to Polaris treatment

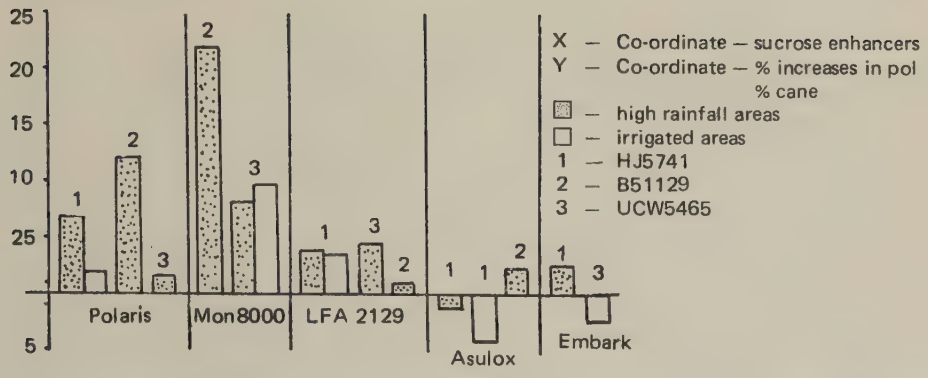

FIGURE 3. Changes in pol %cane content of HJ5741, B51128 and UCW5465 6-8 weeks after chemical application

in the high rainfall areas (+7% pol % cane), it gave little or no response in the irrigated area.

The changes in pol % cane over time for Polaris and Mon 8000 treated canes in the irrigated and high rainfall areas were compared in Fig. 4. Again, the superior activity of both chemicals in the high rainfall area was apparent. Although the activity of Polaris in the irrigated area was insignificant, the trends in pol % cane over time mirrors that of Mon 8000 up to 6 weeks, at which time the activity of Mon 8000 continued to increase, while that of Polaris decreased. In the high rainfall area, substantial pol % cane increases were obtained 6 - 7 weeks after Polaris application and 4 weeks after Mon 8000 application. Again, the activity of Polaris was apparently lost 7 - 8 weeks after spray, while that of Mon 8000 continued to increase.

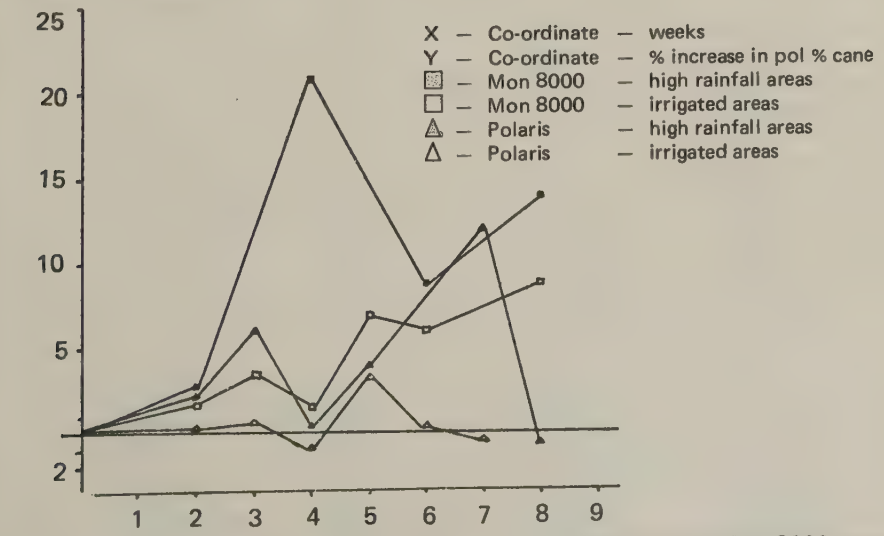

FIGURE 4. Changes in pol % cane over time for Polaris and Mon 8000 treated

TABLE 2. The effect of Polaris on the juice purity and pol % cane of several varieties

	High Rainfall Areas						Irrigated Areas					
			Purity		Pol % Cane				Purity		Pol % Cane	
Crop Period	Variety	No. of Trials	Control	Polaris % Control	Control	Polaris % Control	Variety	No. of Trials	Control	Polaris % Control	Control	Polaris % Control
Early	HJ5741	5	90.39	102	11.61	108*	HJ5741	1	—	—	10.64	106
	B4362	1	85.42	103	10.72	105	UCW5465	4	86.86	102	12.59	100
							B51415	1	—	—	10.92	98
Mid	HJ5741	3	92.58	102	13.84	106	HJ5741	3	—	—	13.00	101
							UCW5465	1	—	—	12.31	102
Late	HJ5741	5	86.07	104	11.97	104	HJ5741	5	—	—	11.49	102
	UCW5465	4	81.01	99	9.03	100	UCW5465	2	89.60	99	9.45	104
	B4362	3	—	—	6.67	104						
	B51129	13	82.78	107	9.88	112**						
Mean		34	85.34	104	9.53	107		17	87.61	101	11.74	104

** Significant increase at the 5% probability level*

*** Significant increase at the 1% probability level*

TABLE 3. The effect of LFA 2129 on the juice purity and pol % cane of several varieties

		High Rainfall Areas					Irrigated Areas					
			Purity		Pol % Cane				Purity		Pol % Cane	
Crop Period	Variety	No. of Trials	Control	LFA 2129 % Control	Control	LFA 2129 % Control	Variety	No. of Trials	Control	LFA 2129 % Control	Control	LFA 2129 % Control
Early	HJ574	2	90.70	100	12.57	101	UCW5465	3	85.86	98	12.35	96
							B51415	1	—	—	10.92	98
							HJ5741	1	—	—	10.64	100
Mid	B51129	1	—	—	12.52	96						
	HJ5741	1	92.67	102	13.66	99						
Late	HJ5741	7	87.02	105	11.70	105	UCW5465	2	85.87	102	9.85	106
	B51129	3	82.78	102	9.71	103	HJ5741	1	—	—	11.53	105
	B4362	1	—	—	10.63	100						
	UCW5465	1	—	—	9.67	105						
Mean		16	87.04	103	11.42	103		8	85.86	100	11.23	101

TABLE 4. The effect of Embark on the juice purity and pol % cane of several varieties

	High Rainfall Areas						Irrigated Areas					
			Purity		Pol % Cane				Purity		Pol % Cane	
Crop Period	Variety	No. of Trials	Control	Embark % Control	Control	Embark % Control	Variety	No. of Trials	Control	Embark % Control	Control	Embark % Control
Early	HJ5741	2	90.70	100	12.88	95	UCW5465	3	86.06	99	12.35	98
Mid	HJ5741	2	92.58	94	13.84	104						
Late	HJ5741	1	85.32	111	13.03	103	UCW5465	1	85.87	86	9.45	98
Mean		5	90.38	100	13.29	101		4	86.01	95	11.63	98

TABLE 5. The effect of Asulox on the juice purity and pol % cane of several varieties

	High Rainfall Areas						Irrigated Areas					
			Purity		Pol % Cane				Purity		Pol % Cane	
Crop Period	Variety	No. of Trials	Control	Asulox % Control	Control	Asulox % Control	Variety	No. of Trials	Control	Asulox % Control	Control	Asulox % Control
Early	HJ5741	2	90.70	101	12.57	98	UCW5465	4	86.91	100	12.59	98
Mid	B51129	1	–	–	10.44	102						
Late	HJ5741	4	88.50	104	13.09	100	UCW5465	2	88.24	94	9.45	91
Mean		7	89.23	103	12.56	99		6		98	11.54	96

TABLE 6. The effect of Mon 8000 on the juice purity and pol % cane of several varieties

	High Rainfall Areas						Irrigated Areas					
			Purity		Pol % Cane				Purity		Pol % Cane	
Crop Period	Variety	No. of Trials	Control	Mon 8000 % Control	Control	Mon 8000 % Control	Variety	No. of Trials	Conrol	Mon 8000 % Control	Control	Mon 8000 % Control
Early							UCW5465	1	84.09	102	12.36	103
Mid							B41227	1	86.64	105	12.13	121**
Late	B51129	1	79.7	110	7.80	122**	BJ5924	1	81.91	99	9.47	102
	UCW5465	1	76.65	103	8.09	108	UCW5465	2	85.61	103	10.95	114**
Mean		2	78.18	107	7.95	115		5	84.77	102.40	11.17	111

*** Significant increase at the 1% probability level*

Mon 8000 therefore increased the sucrose content of sugarcane in both the irrigated and the high rainfall areas, while Polaris treatment resulted in increased sucrose only in the high rainfall areas. Asulox and Embark exhibited little or no sucrose enhancing ability. As a result, routine testing of these 2 chemicals have been discontinued. Testing of LFA 2129 had also been discontinued as the May and Baker Company took a decision not to proceed with its registration.

DISCUSSION

The poor performance of Polaris in irrigated areas was reported from Hawaii (Buren[2]) and elsewhere. This has generally been attributed to moisture stress prior to, and after chemical treatment. From the rainfall data collected during a few trials, there was an apparent positive relationship between rainfall and sucrose enhancement (Table 7).

TABLE 7. The relationship between rainfall and the effect of Polaris on the pol % cane of irrigated and unirrigated sugarcane

Location	No. of Trials	Rainfall (6 weeks) (mm)	Pol % Cane Increase (%)	"r"
Duckenfield Sugar Co. (unirrigated)	6	325.63	10.67	+0.78
Innswood (irrigated)	11	80.77	1.1	−0.16

In most trials conducted in the irrigated area, the cane received the last wetting just prior to treatment. To determine if the resulting moisture stress affected the performance of Polaris, Embark, LFA 2129 and Asulox, 4 trials received a final irrigation after the application of the chemical. Sucrose increases from these tests were also insignificant, probably indicating that factors other than low soil moisture were involved.

As shown in Table 2, the average pol % cane increase following Polaris application was a modest 7% in the high rainfall areas, and an insignificant 2% in the irrigated areas. These results were somewhat similar to the overall 5% increase obtained in commercial applications in Hawaii (Hilton *et al*[7]).

Mon 8000 applications, in contrast, resulted in average pol % cane increases of 11 and 15% in the irrigated and the high rainfall areas respectively. In the irrigated area, however, sucrose increases may be due to growth cessation following Mon 8000 application rather than true ripening as juice purities were unaffected. This aspect is being examined in other trials. Also, the activity of Mon 8000

over time is being further examined, as, from our trials, it appears that its activity is maintained over a longer period than that of Polaris. Similar findings for other glyphosate salts have also been reported (Osgood[11]). This is a particularly desirable feature as it would allow for greater flexibility in harvesting schedules.

On the advice of the Research Institute, farmers in the eastern end of the island have been applying Polaris on a commercial scale from 1977. The economics of application for the main user is given in Table 8. Sucrose increases and, therefore, net returns were greater from applications made during the last 6 - 8 weeks of crop.

TABLE 8. Economics of Polaris application at Duckenfield Sugar Company

	1977		1978
	Early Crop	Late Crop	Late Crop
Approx. hectares treated	50	30	200
Variety	B51129	B51129	B51129
% increase Tons Sugar/ha	7.42	10.87	12.00
Tons Sugar/ha increase	0.12	0.16	0.18
Net returns/ha (J$)	$8.70	$16.70	$16.40

CONCLUSION

Five years of sucrose enhancer research have established the activity of Polaris in non-irrigated canes in the eastern and western ends of the island. B51129, a high tonnage cane, is by far the most responsive. The acreage in this variety is likely to increase as it is resistant to both smut and rust. Embark and Asulox did not ripen cane to any significant extent during the 3 years they were evaluated. LFA 2129 gave moderate sucrose increases in some tests in the late crop period.

Although Mon 8000 has not been tested as extensively as the other chemicals, it had produced sucrose increases superior to Polaris in both irrigated and non irrigated cane. Trials with this formulation are continuing so that its activity throughout the island will be well established by the time it becomes available commercially.

The testing programme has, to date, been primarily concerned with finding out if a particular chemical promotes sucrose accumulation rather than with why it does or does not do so. Now that 2 sucrose enhancers have been identified, some attention will be given to the conditions affecting the activity of these chemicals. The effect of sucrose enhancers on the physiology of the sugarcane plant under varying cultural and environmental conditions will also be looked at. The search

for more efficient ripeners will, of course, continue.

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UN REPASO DE PRUEBAS EN AUMENTAR LA SACAROSA HECHO EN JAMAICA DURANTE LOS AÑOS 1974-1978

T. McCatty

RESUMEN

Se discute el efecto de Polaris, Mon 8000, Embark, Asulox y LFA 2129 en la pureza del jugo 6 contenido de sacarosa de diversas variedades de caña de azúcar en Jamaica durante 1974 a 1978.

Plantaciones pulverizadas con Polaris en la área de grandes lluvias, tuvieron en promedio, 4% de pureza y 7% más de pol % caña, que las plantaciones no tratadas con aumentos máximos que ocurren 6 ó 7 semanas despues de la aplicación. Las plantaciones en las áreas irrigadas no respondieron a Polaris.

El Mon 8000 mostró habilidad definida de aumentar la sacarosa en ambas áreas, la irrigada y la de grandes lluvias, produciendo 11.00 y 15.00% mas Pol % caña en ambas áreas respectivamente. Comparada con Polaris y Mon 8000, Embark, Asulox y LFA 2129 produjeron pequeños o ningún incremento en el pol % caña de las variedades ensayadas. El ensayo de estos tres productos fueron descontinuados al final del cultivo de 1978.

Polaris está siendo usado comercialmente y se continuan las pruebas del Mon 8000.

THE USE OF ASULAM AS A SUCROSE ENHANCER IN SUGARCANE

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ABSTRACT

The results from a large number of tests both on small plot and large block trials, with Asulam as a sugar enhancing agent in cane, are presented.

In trials in the Caribbean, Central and South America and East Africa, Asulam at a dose of 4.5 kg/ha increased sugar yield when applied 5-10 weeks prior to harvesting of the crop.

These increases generally occurred as a result of:

(1) increase in the yield and growth rate of raw green cane,
(2) improvement in the quality of the extracted juice or a combination of both factors

Improvements in sugar yield were generally at their greatest following treatment at the beginning and end of the harvesting cycle and occurred in irrigated and non-irrigated crops, both plant and ratoon.

Asulam produced no undesirable side effects in the crop and slightly improved the speed of burn prior to harvest.

The mechanism which produced these effects is not yet fully understood at present. Further evaluations to determine the criteria for maximum activity of Asulam and to improve its field reliability are still on going.

INTRODUCTION

The activity of Asulam in promoting the growth of sugar cane and improving juice quality was reported in 1974 (Anon[1]). Subsequently, screening tests carried out by the Hawaiian Sugar Planters Association confirmed its activity through injection and microplot evaluations (Nickel Takahashi[2,3]). From 1975 to the present, extensive testing in the USA, the Caribbean, Central and South

TABLE 1. Asulam: Location and type of tests carried out by numbers

Date	Location	Screening microplot/ small plot replicated	Aerial block
Oct 1973	Hawaii	6	
Sep 1974	Hawaii	2	
Sep 1974	Hawaii	1 (Formulation *exp.*)	
Sep 1975	Hawaii	1	
Sep 1974	USA	2	
Aug 1975	USA	7	
Oct 1974	Mauritius	1	
Feb 1974	Tanzania		2
Feb 1976	Zambia		1
Feb 1976	S. Africa	1	
July 1975	Brazil	1	
July 1976	Brazil	4	
July 1976	Brazil		4
Nov 1974	Trinidad		1
Nov 1976	Trinidad	1	
Nov 1977	Trinidad	3	
Nov 1978	Trinidad	3	
Nov 1978	Trinidad		4
Nov 1976	Guyana		1
Feb 1976	Jamaica	1	
May 1976	Jamaica		3
1977	Jamaica		6
1978	Jamaica		3
1979	Jamaica		2
Jan-Jun 1977	Jamaica		16
Mar 1977	Taiwan	1	
Mar 1977	Philippines	1	
1977	Brazil	3	
1978	Brazil	3	3
1977	Peru		3
1978	Peru		8
1977	Colombia		1
1977	Costa Rica		1
1977	Dom. Republic		1
1978	Ecuador		2
1979	Ecuador		2
1978	Venezuela		2
1978	Cuba		1* (100 ha total)
Total	109	42	67

** In a series of blocks*

America and East Africa has been undertaken either in the form of replicated strip tests (aerially and ground applied) or large block trials on a field basis (aerially applied).

The majority of these trials have been carried out by trained technical staff and have been extensively monitored during the course of the test period, particularly during harvesting.

Further evaluation in areas where maximum activity had been produced is envisaged.

EXPERIMENTAL PROCEDURE

The trials undertaken in 1974 until 1979 fall into two main categories and are summarized in Table 1.

Small plot replicated screening trials and microplot tests

Fifty to 100 liters per hectare of water was applied by ground sprayers on plots whose areas reached up to 75 sq. m. In earlier tests, doses of Asulam used ranged from 2.5 kg/ha; in later tests the 4.5 kg/ha rate was chosen as the optimum. Juice quality prior to and during the course of experimentation was monitored. At varying periods during the duration of the tests, two or three harvests were made on sprayed areas. At harvest, juice quality and weight of cane per unit area were taken and recorded.

Large aerial block trials

Aerial application of Asulam, at the rate of 4.5 kg/ha, was made either by fixed wing or helicopter. The application was made on a half field basis to allow for comparison between sprayed and unsprayed blocks. Harvesting was generally programmed for 10 weeks after application. In some cases, due to industrial disputes, harvesting was carried out prematurely or delayed considerably. Data on juice quality were obtained before or during spraying and fields were carefully selected for uniformity of crop stand and ease of harvesting. Further quality samplings were made during the course of the experiments. Crop condition and chemical effects were also assessed. At harvest, cane in sprayed and unsprayed areas was cut and weights per unit area were recorded together with factory juice analyses from several samples in each of the sprayed and unsprayed plots.

Figures for TC/TS ratios, TC/ha, and TS/ha were calculated. In all tests, the Asulam used was the May and Baker commercial formulation *Asulox 40* containing 40% w/v Asulam generally coded as FR 600/1.

RESULTS

Activity of Asulam on increase in sugar yield

Table 2 indicates the various trials which have produced positive and negative effects on TS/ha values.

For the purpose of this resume all increases over 5% were considered of significant positive interest. Changes in TS/ha values between +5 and –5% as compared with the control, were included within the limits of normal error. Those producing more than a 5% decrease in sugar as compared with control were of negative value.

TABLE 2. Activity of Asulam on TS/HA values; Application in relation to pre-harvest interval

Total No. of sites	8-10 weeks or more between spray and harvest		
	Group 1	Group 2	Group 3
61	35	20	6
	5-7 weeks between spray and harvest		
	Group 1	Group 2	Group 3
19	7	6	6
	2-4 weeks between spray and harvest		
	Group 1	Group 2	Group 3
11	4	7	–

Dose rate 4.5 kg/ha Asulam
Group 1 = More than 5% increase
Group 2 = From 5% increase to 5% decrease
Group 3 = More than 5% decrease

Crop yields and foliar symptoms

No significant crop phototoxicity occurred in both small plot and larger

aerial block trials. Visual symptoms following Asulam applications commonly took the form of a very slight chloritic spotting of the older leaves not the plant. No apparent check on the growth of the cane occurred and, as previously stated, there were increases in yield of raw cane following the application of Asulam.

In areas such as the West Indies, Central and South America, testing of Asulam as a sugar enhancer had been most extensive. Test results for these areas are presented in Tables 3 and 4.

TABLE 3. The activity of Asulam as a sugar enhancer in the West Indies – 1976 1979 (Jamaica, Guyana, Trinidad)

No. of sites reported	No. of sites with increased yield	Range%	Mean %
			Tons cane per hectare
34	24	1.7 – 21.2	7.9
			Brix value of juice
29	13	0.4 – 17.0	4.9

DISCUSSION

As can be seen from Table 1, tests carried out with Asulam as a sugar enhancer have covered a very large number of sugar cane areas differing in climate and cultural practices being followed.

Table 2 indicates Asulam's effect on sugar yield per hectare in different test durations. The mechanism behind Asulam's effect on yield is still not understood but certain test areas have shown a greater repeatability of results than others. These situations have the following common factors:

(a) High rainfall or sufficient irrigation.
(b) Absence of pests and disease.
(c) Application of chemical in the beginning and towards the end of the harvesting period.

TABLE 4. The activity of Asulam as a sugar enhancer in South America (Brazil, Peru, Colombia, Ecuador)

No. of sites reported	No. of sites with increased yield	Range %	Mean %
		Tons cane per hectare	
27	15	2.0 – 39.0	13.35
		Brix value of juice	
27	17	2.0 – 14.6	5.2

HJ 5741	CP 52-68	PR 1059
B 51229	L 60-25	H32-8560
B 51227	CP 61-37	PCG 14.745
B 41227	L 62-96	H37-1933
CH 32	CP 63-588	CB 45-3
CP 57603	UCW 5465	CB 5241
CP 48-103		

After the application of Asulam, sugarcane gave a better 'burn' than those in unsprayed areas. The ratoon crop showed little effect from chemical application in the previous season.

The activity of Asulam when used for the increase of sugar yields in cane was somewhat different in other commercially available materials. Asulam increases the sugar content of cane by improving the quality of the juice or by producing a boost on the growth of the crop subsequent to application. In a number of cases however, sugar yields have been increased by a combination of both factors as seen in Table 3 and 4. Its mode of action is best described as that of growth and quality enhancement as opposed to ripener.

From results to date, the optimum timing for application of Asulam as a sugar enhancer is about 10 weeks prior to the projected harvest date of the crop, although tests covering periods of 4 weeks to 22 weeks duration have been undertaken. Economic gains from application of Asulam are minimal if the product is applied less than 4 to 5 weeks before harvest. There appeared to be little; if any, deterioration in sugar yield in the tests covering some 22

weeks, indicating that Asulam stimulates rather than halts the growth of the crop.

Tests results indicated that the maximum increase from Asulam applications occurred in the higher yielding varieties of cane although positive activity with applications (of 4.5 kg/ha) have been obtained in a wide range of varieties including the following:

In all tests to date, the only varieties which have produced little, if any, positive response have been NCO types, mainly in the African continent.

Evaluation of Asulam as a sugar enhancing agent will continue in territories where responses would show commercial viability with a view to eventual sales of the product. Meanwhile, studies of the mode of action of the chemical will continue in an attempt to define the conditions needed to maximize the effects of the chemical on sugar yield per unit area.

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EL USO DE ASULAMMAS – UN ENCARECEDOR EN CAÑA DE AZUCAR

J.A. Hardisty

RESUMEN

Se presentan los resultados obtenidos de un gran numero de examenes llevados a cabo no solo en solares o terrenos pequeños sino tambien en probaduras de cuadros grandes con Asulam usado como agente encarecedor en caña.

En probaduras en el Caribe, Sud America y America Central, y en el Este de Africa, Asulam, en una dosis de 4.5 kg/ha ha producido aumentos en el rendimiento de azucar cuando fue aplicado de 5 a 10 semanas antes de cosechar la caña.

Generalmente estos aumentos han ocurrido como resultado de:

(a) Aumento en el rendimiento y medida de crecimiento de

caña verde en bruto.

(b) Mejoramiento en la calidad de jugo extraido o una combinacion de ambos factores.

Mejoramientos en el rendimiento de azucar eran generalmente mayores despues del tratamiento al principio y al fin del ciclo de cosecha, y han ocurridos en campos irrigados como tambien en campos no irrigados, y no solo en plantas sino tambien en vastagos (ratoons).

Asulam no produjo efectos indescables en la cosecha y mejoro un poco la rapidez del quemo antes de la cosecha.

El mecanismo que ha producido estos efectos todavia no son completamente entendidos actualmente y mas evaluaciones estan bajo investigacion para determinar la base para la maxima actividad de Asulam tambien para mejorar su seguridad de uso en el campo.

SOME ASPECTS OF MON 8000 AS A SUGARCANE RIPENER TO REPLACE POLARIS

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ABSTRACT

The glyphosate salt formulation designated as MON 8000 showed considerable promise at 0.25 to 1.0 kg/ha (acid equivalent basis) as a sugarcane ripener. Its activity at these dosages has been at least equivalent to that of glyphosine (in the Polaris formulation) at 4.5 kg/ha. It also gave rise to more consistent responses in different climates. The effects of MON 8000 on sugarcane growth, sucrose production and storage, and on ratoon regrowth depended upon the amount and concentration of glyphosate applied to the foliage and on the time between application and harvest. Most of the observed climatic and cultivar differences in response to MON 8000 were probably due to the maturity of the treated stalks in relation to temperature, nutrients, and water at the time of application and to the ripening period from application to harvest.

INTRODUCTION

In 1974, Selleck *et al*[9]. reviewed the experimental field use of Monsanto sugarcane ripener Polaris in Hawaii. The active ingredient, glyphosine, had enhanced sucrose in the 1969 HSPA screening (Nickell[6]). Laboratory and field development, plus the lengthy governmental review, culminated in the approval for the commercial use of Polaris in March, 1975 (Buren[1]). At present, about 65% of the harvested area in Hawaii is treated with Polaris.

Polaris ripens cane under less-than-favorable natural conditions by retarding apical growth while synthesis, transport, and storage of sucrose continue. The advantages of this type of chemical ripening were apparent on improved juice quality and higher potential sugar yields, better raw juice color, juice preservation from field to mill, and its use under conditions of less favorable climate, nutrition, and temperature. Hawaii's extremely variable climate, the long harvesting period of 9 months or more per year, and the presence of immature suckers in the 2 year-old crop favor a ripening program that will optimize juice quality throughout the year.

Under prevailing field conditions, a number of important cultivars do not respond to Polaris. If they do, response diminishes markedly where soil and plant nitrogen are in excess of natural ripening requirements. In the intensive search for

a better product, HSPA first tested in 1970 another Monsanto chemical that had ripening properties superior to Polaris. Precedence was given to the development of Polaris and only in 1975 (Maretzki *et al*[4]) were formulations of this highly active ripener identified as containing glyphosate salts. Although all formulations of glyphosate have given essentially equivalent results at comparable application rates and volumes, most of our recent work has been with the product designated as MON 8000, a sodium salt of glyphosate.

In this paper, we discuss a number of measurements which have been made in the development of MON 8000 as a ripener, either in comparison with Polaris or with an untreated control.

MATERIALS AND METHODS

Field experiments

MON 8000 was applied over cane at rates ranging from 0.25 to 1.0 kg/ha in a volume of 95 L/ha, using a truck-mounted boom capable of spraying a swath 10 meters in depth. Prior to application, stalks for sampling were "benchmarked" with paint at the 13th internode (the spindle leaf is counted as No. 1). Stalks with Polaris, other ripeners and no treatment (control) were also marked. After the treatment and ripening period, the marked portions were cut and the juice was analyzed for pol, refractometer solids, and purity. This takes into account growth differences between treatments. For some experiments, the 13 internodes below the marked portion were also taken for juice analysis, and for some the entire stalks (about 60 to 65 internodes for 2-year-old cane) were harvested.

Stalk weights were obtained for some of the experiments and component analysis was made for fiber, moisture, pol, reducing sugars, and ash. Estimated final molasses purities and recoveries of sugar and molasses were calculated by the SJM formula from mixed juice data obtained from the HSPA Mini-Factory processing of treated cane (Rhodes[8]).

Laboratory and greenhouse experiments

Glyphosate was applied to the top four leaves of young sugarcane in amounts ranging from 1 to 12 mg per plant. At an assumed average of 66,000 stalks per hectare at maturity, 5 mg corresponds to about 0.33 kg/ha. In some experiments, radiolabeled ^{14}C-glyphosate was applied as a tracer. In other experiments, unlabeled glyphosate was used, followed by $^{14}CO_2$ fed to the leaves in order to determine the effects of glyphosate on photosynthesis.

RESULTS

Effect of MON 8000 on juice quality of mature cane

Preliminary field work with MON 8000 established that optimum response as measured by pol increases as a percentage of fresh cane weight (pol % cane), occurred at 0.3 to 0.75 kg/ha and at 6 to 12 weeks after treatment. Climatic

cultivar, water, and nutritional differences accounted for the observed variability. Within the limits set by the test program, chemical ripening with MON 8000 has been a function of dosage, time, and the juice quality of the cane at the time of application.

Table 1 summarizes 20 field experiments in which pol % cane of MON 8000 at two application rates was compared with Polaris, an untreated control, and two other growth regulators, Embark and Ethrel. Averages for juice samples from the benchmarked top portion of the stalk were taken between 8 and 12 weeks after treatment, and therefore represented changes in the least mature part of the stalk only. Tests are averaged by cultivar, and represented mainly unirrigated conditions.

That ripening also took place in internodes below the benchmarked upper portion is illustrated in Table 2 from tests at two locations. In some instances, Polaris at 4.5 kg/ha had performed as well as MON 8000 at nearly 1/10 of the amount of active ingredient, when only the benchmarked top internodes were considered. Generally however, MON 8000 induced superior ripening of lower internodes or the whole cane.

TABLE 1. Summary of response to ripeners as pol percent cane*

		Average pol 5 cane and percent change for treatments in kg/ha					
		MON 8000		Embarck	Ethrel	Polaris	Control
Cultivar	N	0.3	0.6	1	1	4.5	–
H59-3775	9	14.29	15.43	11.19	10.33	13.67	10.95
% Change		30	41	2.2	–5.7	25	–
H57-5174	4	11.34	11.62	10.50	10.91	10.60	10.71
% Change		5.6	8.5	–2.0	1.9	–1.1	–
H54-775	2	11.05	12.25	9.85	10.08	11.68	10.99
% Change		0.5	20	–10	–8.3	6.3	–
H61-467	2	11.44	13.79	11.39**	9.87	10.63	9.51
% Change		20	45	20	3.8	12	–
H56-4848	1	10.02	11.53	9.87	9.74	9.83	9.60
% Change		4.4	20	2.8	1.4	2.4	–
H60-7490	1	8.12	10.19	8.52	8.92	9.30	8.87
% Change		–8.5	15	–4.0	0.5	4.8	–
H56-278	1	13.55	14.83	13.02	12.78	13.29	12.82
% Change		5.7	16	1.5	–0.4	3.7	–

* *Benchmarked 0-13 internodes. Averages for 8 and 12 week data.*
** *N = 1*

Calculated recovery of sugar and molasses as percent of green weight of cane

Whole stalks harvested at 19.5 months of age and processed in the HSPA Mini-Factory were analyzed for the material balance study on fresh weight.

TABLE 2. Effect of MON 8000 and Polaris on pol in juice from the top and upper middle sections of sugarcane*

Treatement	Pol % cane			
	Puna Sugar Co.		Mauna Kea Sugar Co.	
	Top	Middle	Top	Middle
Control	6.68	14.11	9.75	15.72
Polaris 4.5 kg/ha	9.67	15.00	14.41	17.21
MON 8000 0.6 kg/ha	14.04	17.07	13.49	17.90

* *2 locations, cultivar H59-3775*

The results are shown in Table 3. The three dosage rates of MON 8000 and one of Polaris reduced moisture content, increased pol and fiber (as percentages of the fresh weight), and drastically lowered the reducing sugars, in comparison with the untreated control.

The decrease in the ratio of reducing substances to soluble ash in the mixed juice from MON 8000 or Polaris is an indication that final molasses purities will be higher and that at least a portion of the pol increase in the juice may not be recoverable as crystalline sucrose. The mixed juice data were used to calculate expected recoveries of sugar and final molasses by the SJM formula. While molasses purities in this experiment were higher from cane treated with MON 8000 or Polaris, as expected, the calculations showed that there should be substantial recovery of the increased pol as sucrose and no drastic change in quantities of final molasses. These data will be verified further by molasses exhaustibility trials.

Estimation of cane and sugar yields per unit area

From an analysis comparing 48 untreated individual stalks with cultivar H54-775 treated with MON 8000 at 10 months of age, (Tables 4 and 5) it is possible to estimate changes in sucrose yields per stalk based on the weight changes in moisture, pol, and dry fiber that occurred during ripening. Although growth (stalk length and numbers of new internodes) and juice purity changes were the least variable, dry weight measurements were most useful for estimating yields when larger treated blocks were not available for harvest. An estimate of yield changes in cane and sucrose per hectare can be made by extrapolation of the single-stalk data.

Laboratory and greenhouse studies

From our studies with radiolabeled glyphosate (Nomura[7]) it was clear that the active molecule is rapidly translocated to the apical region of the stalk after application on leaf blades. Glyphosate was also distributed into other portions of the plant such as the stalk and roots. With time, the radioactive gradient down the stalk tended to distribute more uniformly throughout the stalk. Implications of these studies, depending on chemical concentration and time, are for germination of buds from treated stalks and for ratoon regrowth. Germination of nodal buds or ratoon shoots

TABLE 3. Effect of MON 8000 and Polaris on fresh weight and juice components; estimated sugar and molasses recoveries and molasses purities[a]

Component	MON 8000 (kg/ha) 0.23	0.46	Control A[b] Polaris (kg/ha) 0.68	4.5	Control B[b] –
			Material balance as % of fresh weight		
Water	69.80	68.50	67.86	73.93	68.12	73.40
Pol	14.17	14.93	15.56	11.00	15.26	11.27
Fiber	14.81	15.52	15.40	14.04	15.63	13.93
Reducing sugar	0.25	0.10	0.10	0.26	0.26	0.42
Ash	0.20	0.25	0.29	0.19	0.28	0.21
ONS[c]	0.77	0.70	0.79	0.58	0.61	0.77
			Mixed juice analysis (% on mixed juice)		
Ref. solids	11.42	12.20	12.73	8.91	12.09	9.07
Pol	10.52	11.39	12.83	8.09	11.35	8.07
Reducing sugar	0.18	0.08	0.07	0.24	0.08	0.30
Ash	0.15	0.19	0.22	0.15	0.21	0.15
ONS	0.57	0.54	0.61	0.43	0.45	0.47
Purity	92.18	93.36	92.93	90.80	93.88	88.97
			Estimated expected recovery and molasses purity[d]		
Reducing subs/ash ratio	2.33	1.37	1.18	2.47	1.24	2.87
Calc. molasses purity	32.87	37.48	38.40	32.20	38.11	30.28
SJM recovery (%)	95.42	95.29	94.76	94.79	95.53	94.24
Tons pol/100 tones cane	13.32	14.03	14.63	10.34	14.34	10.59
Tons 96DA sugar/100 cane	13.49	14.20	14.72	10.41	14.55	10.60
Tons pol in molasses	0.67	0.73	0.85	0.60	0.71	0.67
Tones 85% molasses/100 cane	2.18	2.07	2.36	1.97	1.98	2.37

[a] *Waialua Sugar Co. Experiment 78 r-1, whole stalks including leaves and tops. Mini-Factory processing, cultivar H59-3775, harvested at 19.5 month of age, 3 replications.*

[b] *MON 8000 and Control A harvested at 8 weeks, Polaris and Control B at 10 weeks.*

[c] *Organic non sugars by difference.*

[d] *Based on SJM formula, assuming 1.5% inversion during processing, and typical values for points above expected, for ref. sucrose purity, deleaded port purity, and for sucrose purity.*

mobilized the glyphosate residues into the area of metabolic activity. The visual effects ranged from stimulation to stunting. Multiple tillers often appeared at higher concentrations, sometimes deformed or with a temporary chlorosis. Inhibition of growth or death of a tiller resulted in the appearance of another tiller until the chemical pool was depleted (unpublished HSPA data). The multiple tillers did not persist. By 7 months, the treated plots had the same number of stalks as the untreated.

Also, it appeared that multiple-tillered plants and untreated plants had the same green weight at the same age. The bunchy plant showed reduced growth of the primary stalk as long as the excessive tillering persisted. Germination of nodal buds was more sensitive to low phytotoxic levels of glyphosate than ratoon regrowth. Shorter periods of ripening between application and harvest produced fewer effects in the following ratoon.

In one field test, at rates up to 2 kg/ha, we found only temporary stunting at 1 kg and 2 kg/ha, with possible stimulation at 0.6 kg (Table 6). Ratoon weights at 5 months paralleled the height.

TABLE 4. Effect of MON 8000 on various growth and ripener parameters on an individual stalk basis

Measurement	MON 8000	Control	C.V.	F	Level of significance
					%
No. of internodes	17.2	22.7	4.8	779	1
Stalk length (cm)	310	381	8.3	156	1
Fresh weight (g)	1821	2023	17.6	8.7	1
Percent dry weight	261	21.7	13.9	43	1
Dry weight (g)	488	446	25.3	3.0	10
Refractometer solids (% juice)	16.9	12.1	15.4	108	1
Pol (% juice)	82.4	71.1	8.3	76	1
Fiber % cane)	11.5	11.3	12.7	0	NS
Refractometer solids (% cane)	14.9	10.8	14.6	121	1
Pol (% cance)	12.5	7.7	22.0	112	1
Pol per stalk (g)	232	158	29.5	40	1
Fiber per stalk (g)	209	228	24.9	3.2	10

**N = 48 for treated and control, HSPA Kunia Station, cultivar H54-775, 10 months of age, whole stalks, 8 weeks after treatment.*

TABLE 5. Effect of MON 8000 on individual stalks.*

	MON 8000	Control	Net Change	Significance at 5% level
Fresh weight (g)	1821	2023	−202	yes
Dry weight (g)	488	450	+ 38	yes
Water (g)	1333	1573	−240	yes
Pol (g)	228	156	+ 72	yes
Fiber (g)	205	228	− 23	yes
Pol (% cane)	12.5	7.7	+ 4.8	yes
Fiber (% cane)	11.5	11.3	−	no
Purity	82.4	71.1	+ 11.3	yes

**HPSA Kunia Substation, cultivar H54-775, 48 treated stalks, 48 control stalks, 10 months of age.*

TABLE 6. Summary of ratoon growth data in cm from ground to first visible dewlap.

Treatment	Rate Kg/ha	Days after ratooning		
		85	126	167
MON-2139	0.6	59.7*	145.0	232.2
MON-2139	0.8	58.5	139.0	224.0
MON-2139	1	51.4	129.4	221.0
MON-2139	2	54.2	137.8	221.9
XHH-148	0.6	63.5	151.5	232.7
XHH-148	0.8	62.8	144.8	226.2
XHH-148	1	54.6	125.0	197.5
XHH-148	2	48.3	119.0	194.5
Polaris	4.5	56.5	134.7	214.9
Polaris	9.0	56.1	132.6	213.0
Control	—	—	130.9	213.2
Control	—	—	140.8	226.3

* *Average of 30 measurements (10 per rep.), cultivar H59-3775, HSPA Kunia Substation, MON-2139 and XHH-148 were experimental glyphosate formulations.*

TABLE 7. Effect of potassium ion on ripening with MON 8000*

	Sucrose analysis in internode No. 5 (mg/g dry wt)	
	at 10 days	at 14 days
Control	62.7	58.4
K^+ alone	88.3	56.5
MON 8000 alone	158.7	328.2
MON 8000 + K^+	208.6	476.9

* *Cultivar H59-3775, 4½ months of age. K^+ at 60 mg/plant and MON 8000 at 6 mg/plant applied to leaves.*

We have noted an effect of K+ ion on the sucrose transport out of the leaf to the vascular stream (Maretzki and dela Cruz[5]). Addition of K+ to MON 8000 at the time of treatment increased the sucrose in internode No. 5 over the increase due to MON 8000 alone (Table 7). The effect appeared within 10 to 14 days after treatment, and may be limited to certain internodes, or may reflect an increase in the ripening rate.

DISCUSSION

Juice quality as a measure of sugarcane ripening

Sugarcane ripening involves sacrificing the growth potential near the end of the crop period to increase the storage period of sucrose as long as possible. Juice quality has traditionally been improved by the manipulation of moisture levels in irrigated areas, timing of nutrient applications (especially nitrogen), and restriction of harvesting schedules for more favorable climatic conditions.

Since most of the ripening effect occurs in the less mature upper part of the stalk, there will be less overall improvement in Hawaii's 2-year-old cane than in a younger crop. Based on mill data (which paired Polaris treatment with an untreated control), from 563 field blocks of 2 to 4 hectares harvested at an average age of 2 years under all conditions, weighted average increase of 0.7 ton of sugar per hectare or about 3.5% for all cultivars could be demonstrated for irrigated conditions and 1.4 ton/ha for unirrigated areas (Buren[2]). Most of the gains resulted from the superior response of one major commercial cultivar, H59-3775, which increased 1.7 tons/ha in 192 paired unirrigated blocks and 0.9 tons/ha in 116 irrigated blocks.

Polaris has been applied as facilitator to natural ripening. Water, nutrient, and climatic conditions (harvesting schedules) have not been altered in any way. Response to Polaris treatment has been dependent on the degree of natural ripening attained, as well as on the expression of cultivar differences. Cultivar response appears, at least in part, to depend on environmental factors such as water, nutrient, and temperature ranges and on the juice quality attained as the result of these factors.

MON 8000 appears to be similar to Polaris in its mode of action, although it had about a 10-fold increase in activity per unit of active ingredient (Hilton *et al*[3]). The economic benefit of MON 8000 at 0.5 kg/ha over Polaris at 4.5 will be substantial. MON 8000 has been more consistent than Polaris, with less cultivar differences and less apparent sensitivity to conditions of excess nitrogen.

Effect of chemical ripeners on yield and composition

Most of the data developed for Polaries and for MON 8000 have been based on improvements in juice quality, or in pol per 100 cane on a green weight basis, over the untreated controls. Little consideration has been given to changes in composition of the cane such as in terms of moisture levels and dry fiber weights.

With the data in Table 5, it is possible to estimate component changes in yield per unit area from an application of MON 8000, in comparison with a control , assuming a constant population of 66,000 stalks per hectare throughout the ripening period. Such a calculation is shown as follows:

Fresh weight loss (10%)	13.2 tons/ha
Moisture loss	15.8 tons/ha
Fiber loss	1.5
Pol increase	(4.8)
Ash, reducing sugars, and organic non sugars, by difference	0.7
Net loss	13.2

At a cane age of 10 months, the changes were greater than those expected at 2 years of age. It is apparent from these figures that a sugar increase per unit area should result from an increase in grams of pol per stalk on a dry weight basis, provided we can assume equal stalk populations in the treated and untreated areas and that there is little change in population during ripening. Even though the pol per stalk (in grams) was quite variable (Table 4), the differences between treated and untreated stalks in a population of 48 stalks were adequate for a significance level of 1%. It may be possible to reduce variability by sampling stalks of similar ages or including stalk diameters as a measure of volume.

The effect of MON 8000 on cane biochemistry

Greenhouse studies with MON 8000 showed that the rate of $^{14}CO_2$ fixation in leaves of treated plants remained unchanged, and that translocation rates, likewise, were not retarded by the chemical. Growth was severely retarded, and it was not surprising to find that less of the newly fixed carbon appeared in cell walls of young internodes. Less new carbons were also shown in reducing sugars, but more radioactivity appeared in sucrose. The specific activity of the sucrose in the young internodes indicated that the turnover rate of existing sucrose was decreased, as would be expected with a diminished demand for sugars for growth and respiration. Invertase activity declined severely in the ripened internodes, and decreased markedly even within 24 to 48 hours after MON 8000 applicaton. Other enzymes were also affected — indole acetic acid oxidase, polyphenol oxidase, and a number of others showed similar trends, suggesting widespread inhibition of protein synthesis. This enzymatic effect preceded the increases in sucrose and decreases in reducing sugars by several days.

The laboratory studies with radiolabeled glyphosate have implications for ratoon regrowth. Translocation of active ingredient depended on concentration and on time. At the expected field rates of 0.4 to 0.6 kg/ha for glyphosate as MON 8000, there should not be evident ratoon effects. More data are needed, since there may be climatic differences in growth, and since aerial swath overlap may increase application rates on limited areas while decreasing them in others.

CONCLUSION

In conclusion, MON 8000 has been found to be a superior ripener to Polaris for Hawaiian sugarcane. There is continued interest in the development of MON 8000 and other ripeners with similar properties. It is evident from other studies

that Ethrel, and possibly other chemicals, have potential for increasing growth and cell volume wherein additional sucrose can be stored, even though ripening as we have defined it, has not occurred.

Finally, the potential for increased yields needs to be explored by irrigating and fertilizing cultivars of high yield potential nearer harvest, than is currently practiced, followed by rapid chemical ripening. We view the work done so far on ripening and on the effects of other regulators of growth, as only a small part of the potential in increasing the yields of sugar per unit area.

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ALGUNOS ASPECTOS DEL MON 8000 COMO UN MADURADOR DE LA CAÑA DE AZUCAR EN REEMPLAZO DEL POLARIS

H. W. Hilton, R. V. Osgood, and A. Maretzki

RESUMEN

La formulacion de la Sal del Glifosato designado MON 8000, demostró ser considerablemente promisoria como madurador de la caña de azucar a dosis de 0,25 a 1,0 Kg/ha (equivalente acido) Su actividad a estas dosis ha sido al menos equivalente a 4,5 Kg/ha de la glifosina (en la formulacion del Polaris), con mas consistencia de respuesta en diferentes climas.

Los efectos del MON 8000 sobre el crecimiento de la caña de azucar, produccion y acumulacion de sacarosa y sobre el rebrote de la Soca, dependió de la cantidad y concentracion del glifosato aplicado al follaje sobre el tiempo que media entre aplicacion y cosecha. Muchas de las diferencias varietales y de las observaciones climaticas en la respuesta al MON 8000 fueron probablemente debidas a la maduracion de los tallos tratados en relacion a la temperatura, nutrientes y agua a la epoca de aplicacion y durante el periodo de madurez desde la aplicacion a la cosecha.

CHEMICAL RIPENING OF VARIETY B41227 IN TRINIDAD

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ABSTRACT

Nine micro-plot cane ripener trials were conducted from 1976 to 1979 in Trinidad on sugarcane variety B41227. The objective was to screen products which were more capable than Polaris in enhancing sucrose content of this variety for a longer period, to a greater extent, and under a wider range of conditions. Adverse side effects such as growth cessation, reduction in cane weight, desiccation and poor ratooning, commonly reported to occur with the use of Polaris ripeners were studied simultaneously for all products.

Glyphosate-based products, Mon 2139, XHH 148 and Mon 8000 were all found to be superior to Polaris as indicated by increases in pol % cane. Embark-2-S and Ethrel were less effective than Polaris, while FR 600/1 was observed to be unresponsive. Growth cessation, reductions in cane weight and desiccation were all found to occur to small extents with most ripeners, but were not always associated with sucrose enhancement. Untreated cane also underwent similar changes, but to smaller extents. Ratoon regrowth was not adversely affected by any ripener.

INTRODUCTION

The major sugarcane variety in Trinidad, B41227, attains optimum maturity about six weeks after the commencement of the harvesting season, and there has long been the need to improve its juice quality during this period. Over the years many ripeners have been tested and from these trials Polaris has emerged as the most promising (Mason[7]) even though there was an uncertainty about the onset, peak level and duration of its induced sucrose enhancement. Further studies which revealed that responses were generally greater and more assured on heavy textured soils (Mason[8]), have reduced the uncertainty to a limited extent. It was thus decided to test new ripeners reported to be successful in other countries (Eastwood[2], Hilton *et al*[3], Samuels and Alers[10]). It was also felt that ripeners which were capable of giving a faster onset and longer duration of sucrose enchancement would allow more flexible harvesting.

The need to improve experimental precision by reducing variation (Julien[5]

led to the change from large aircraft-sprayed trials to replicated micro-plot ones, which could be subjected to proper statistical analysis. This was especially desirable because many products were available only in limited quantities. In addition to evaluating new ripeners against Polaris, the opportunity was taken to re-evaluate Ethrel, in the light of reports of its effectiveness in Southern Africa and Columbia (Rostron[9], Jaramillo *et al*[4]), and also to check widely reported side effects, such as growth cessation, weight loss, desiccation and poor ratooning (Alexander[1]. Hilton *et al*[3], Julien and Goolamhossen[6]).

In this paper, the results of nine micro-plot trials conducted during the past three years are presented.

MATERIALS AND METHODS

The trials were carried out according to a randomized complete block design with four replications each, except for trials 1 and 4 which had three replications each. Each plots consisted of 4 rows which each is 6 meters long. Between plots 2, guard rows were left to allow for drift. Application was by means of a Solo mist blower set to deliver approximately 1 liter per minute. The application time was about 25 seconds per plot. Each plot thus received about 0.5 liters of spray solution (125 liters per hectare). Details of the chemical ripeners used are given in Table 1. Data on trial locations, soil types, initial juice purity and pol % cane are presented in Table 2.

Just prior to application and at about 14 days intervals afterwards (as far as possible), five cane samples, topped at the TVD were taken from each plot for cane weight determinations and juice analysis, according to the Press-method (Tanimoto[11]). Stalk heights from soil level to TVD were recorded at the start and repeated at 4-week intervals when possible.

RESULTS AND DISCUSSION

Physiognomic effects:

All of the chemicals caused leaf discoloration within one week after application. The discoloration was similar in most cases. Initially, it appeared as a yellowing mainly along the tips and margins near the proximal ends of the leaf lamina. Reddish-orange specks sometimes accompanied the yellowing. After about three to four weeks, these discolored areas became completely dry. All canes treated with Polaris in trials 3, 4 and 5 have their foliage completely dry at 10 to 12 weeks after application. In the other trials however, only a small percent of the canes were similarly affected. The extent of foliage drying with most of the other ripeners varied widely but completely drying was never observed. FR 600/1 was the only chemical which gave consistently small percentage of canes having dry foliage.

Another commonly observed feature was the general reduction in spindle

TABLE 1. Details of cane ripeners, rates and trials in which they were applied

Product	Common name	Formulation	Rate kg. a.i./ha	Manufacturer	Trials
Embark-2-S	undecided	480 a.i./a	1.12	3M Company	1–9
Ethrel	Ethephon	392 a.i./1	0.72 and 1.30	Amchem	1–9
FR 600/1	Asulam	400 a.i./1	4.50	May and Baker	2–9
Mon 2139	Glyphosate	300 g a.e/1	0.45	Monsanto	1–5
Mon 8000*	Glyphosate	60% W.S.P.	a-0.54, b-1 .08	Monsanto	6–9
Polaris	Glyphosine	85% W.S.P.	3.80	Monsanto	1–9
XHH148	Glyphosate	60% W.S.P	a-0.45, b-0.90	Monsanto	1–5

**recommended by manufacturer to replace Mon 2139 and XHH 148 in 1976*

TABLE 2. Details of cane ripener trials

Trial No.	Location	Soil Type**	Applic^{n} date	Initial Purity	Initial Pol % cane	Duration days
1	W'loo–Est. 115	SCL	27/11/76	81.34	11.13	68
2*	Caroni-Fred. 75678	SCL	4/12/76	85.70	11.07	33
3	Felicite-A24	SCL	24/11/77	83.99	10.95	102
4	Caroni-W49	CL	28/11/77	86.04	10.94	103
5	Caroni-Fred. 167	C	2/12/77	77.08	9.31	104
6	Felicite-14W4	C	25/11/78	79.37	11.06	101
7	Felicite-Est. 23	CL	2/12/78	76.95	9.96	63
8	W'loo-Wd. 6	SCL	7/02/79	85.19	13.04	78
9	Caroni-Fred. 147	C	12/02/79	79.89	10.91	88

* *harvested commercially by mistake.*

** *C – clay; CL – clay loam; SCL – sandy clay loam.*

length, which occurred in canes subjected to all the ripeners except FR 600/1.

Side shooting of cane was observed in all trials and found to occur with all the chemical ripeners applied, except FR 600/1. Side shooting may have ensued because the apical meristem activity may have been reduced or completely curtailed (the latter cane have occured most likely where spindles had subsequently dried out). Though the extent of side shooting in canes varied widely with individual chemicals, Mon 8000 caused a relatively high proportion of canes to side shoot compared to Embark, Ethrel and Polaris. It was not possible to make conclusions for Mon 2139 and XHH 148 because the data obtained was for only one trial.

Effects on Cane Growth:

The effects of cane ripeners on cane growth varied. Table 3 gave the mean daily increases in stalk heights for the various treatments, Embark, Ethrel and FR

600/1 did not adversely affect growth in some trials, the mean daily increases in stalk heights were greater than that of untreated cane. Cane treated with XHH 148 gave mean daily increases in stalk heights similar to untreated cane in the remaining trials. It should be emphasized that even in the untreated plots, the rate of stem elongation was less than 20% of that occurring during the period of most rapid growth (July to October). This is consistent with the finding reported for cane growing under Trinidad conditions during the ripening period of December to January (Mason[7]). Thus, in absolute terms, the curtailment of growth due to any of these cane ripeners was small.

TABLE 3. Mean daily increases (cm/dy) in stalk height in cane ripener trials

Treatment	Trial No.								Mean
	1	3	4	5	6	7	8	9	
	Days after application								
	32	28	30	28	45	45	32	32	
Control	0.32	0.17	0.18	0.41	0.23	0.20	0.02	0.19	0.22
Embark-2-S	0.29	0.34	0.43	0.31	0.28	0.27	0.07	0.14	0.27
Ethrel	0.48	0.31	0.54	0.34	0.45	0.27	0.09	0.13	0.30
FR 600/1	–	0.24	0.18	0.38	0.26	0.28	0.09	0.14	0.22
Mon 2139	0.10	0.14	0.25	0.14	–	–	–	–	0.16
Mon 8000_a	–	–	–	–	0.11	0.09	0.01	0.09	0.08
Mon 8000_b	–	–	–	–	0.10	–	0.04	0.01	0.05
Polaris	0.23	0.31	0.18	0.10	0.02	0.23	0.06	0.09	0.15
XHH 148_a	0.32	0.21	0.07	0.41	–	–	–	–	0.25
XHH 148_b	0.10	–	–	–	–	–	–	–	

Pol % cane:

The pol % cane due to individual ripeners varied both within and among trials, with CV values ranging from 3 to 10% (Mean 6%). Changes of this level were not fond to be statistically significant. The changes in pol % cane relative to untreated cane induced by the various ripeners at all samplings for all trials are presented in Figures 1 to 3.

The standard ripener, Polaris, gave significant increase ($P = 0.05$) in trials 5 and 6 where increases in pol % cane in excess of 25% and 15% respectively, were obtained (Fig. 1). These large responses seem to be due to heavy soil texture, resulting from slow cane maturation which in turn, is caused by the slow rate of soil drying. This is consistent with earlier findings by (Mason[8]). In other trials, except trial 9, fairly consistent increases of about 4 to 8% were recorded (not sig $P = 0.05$). In tiral 9, there was a marginal but consistent reduction in pol % cane.

Mon 2139, Mon 8000 and XHH 148 (all glyphosate-based products) gave larger and more frequent improvements in pol % cane than that obtained with Polaris

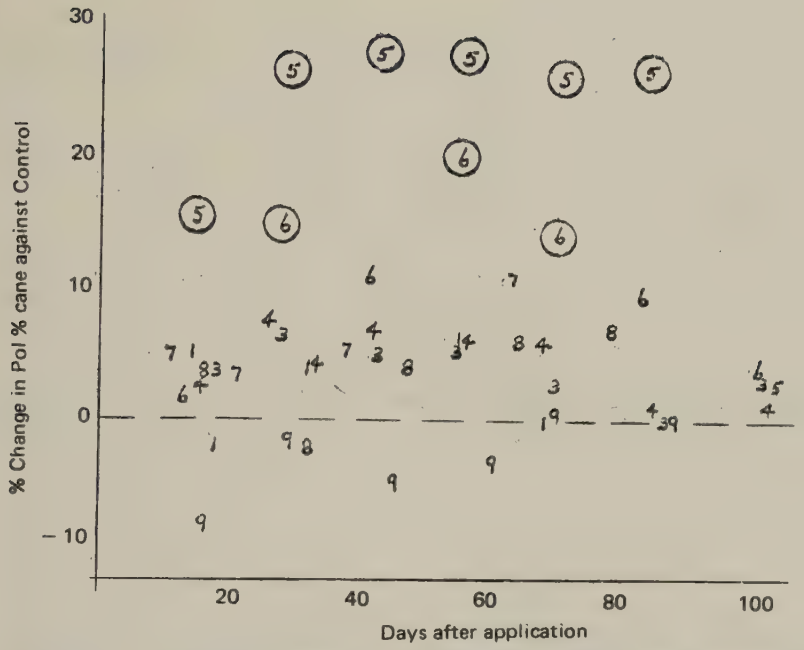


FIGURE 1. Per cent changes in pol % cane relative to controls with Polaris cane ripener

(Fig. 2). Mon 2139 was the most effective product (formulation), giving significantly higher (P = 0.05) pol % cane levels compared with untreated cane in the large majority of samples of the five trials in which it was used. Both Mon 8000 and XHH 148 gave significantly higher (P = 0.05) pol % cane levels in the minority and marginal increases (not significant P = 0.05) in the majority of samples. Mon 8000 however have larger pol % cane increases (up to 30%) than that in untreated cane, while with XHH 148, more moderate increases of up to 15% were recorded. Mon 8000 was found to be more effective than Polaris in improving sucrose content even when applied in the middle of the harvest season, as was done in trials 8 and 9. From the results of trial 6, Mon 8000 at the higher rate seemed more effective than the lower rate in enhancing sucrose content on the incline phase of maturation. This was less obvious when applied in the mid-season (trials 8 and 9). These findings needs further investigations.

The duration of sucrose enhancement with glyphosate-based products varied from one trial to the other as with Polaris, but on the whole, it was found to be generally longer than Polaris – becoming large as early as two weeks after application and remaining so after 12 weeks in many instances. These findings suggests those of Eastwood[2], Hilton *et al*[3], and Samuels and Alers[10].

Embark, Ethrel and FR 600/1 generally gave lower pol % cane levels than Polaris (Fig. 3). In fact, Ethrel and FR 600/1 gave marginally lower pol % cane levels than the controls in the majority of samples. Of these two products, FR 600/1 gave poorer results and was thus shown to be ineffective. Embark was better

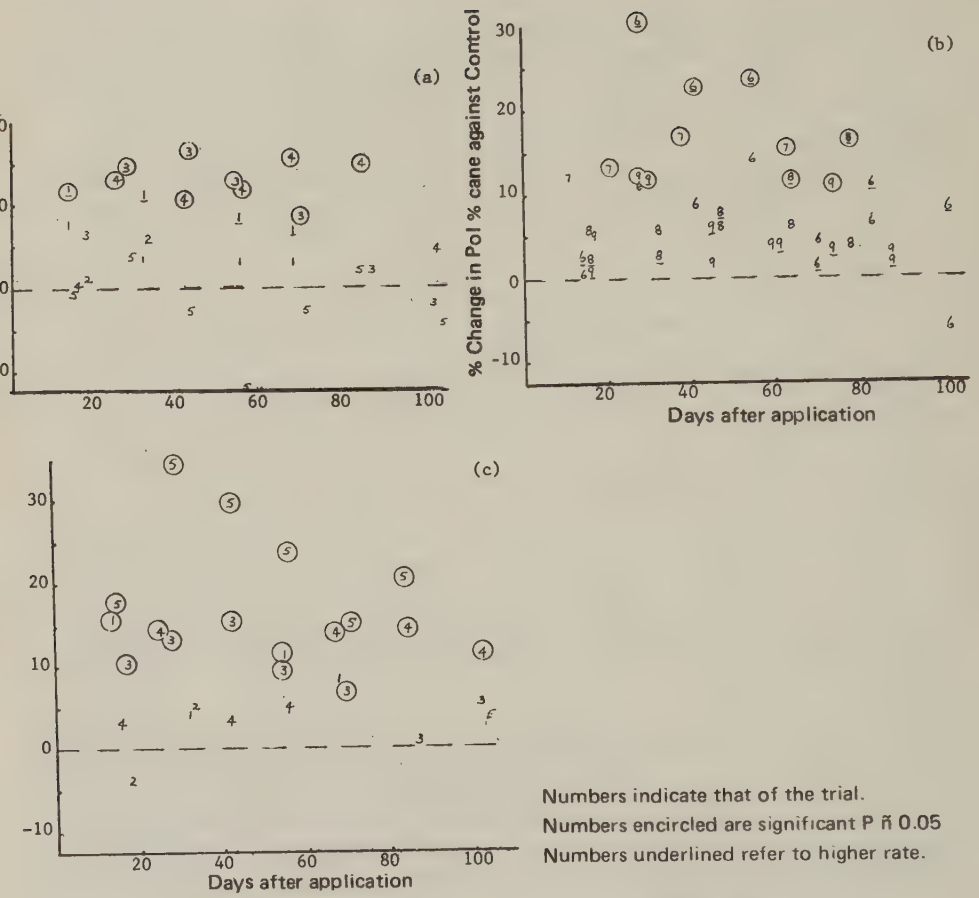

(a)
(b)
(c)
% Change in Pol % cane against Control
Days after application
Days after application
Numbers indicate that of the trial.
Numbers encircled are significant P ñ 0.05
Numbers underlined refer to higher rate.

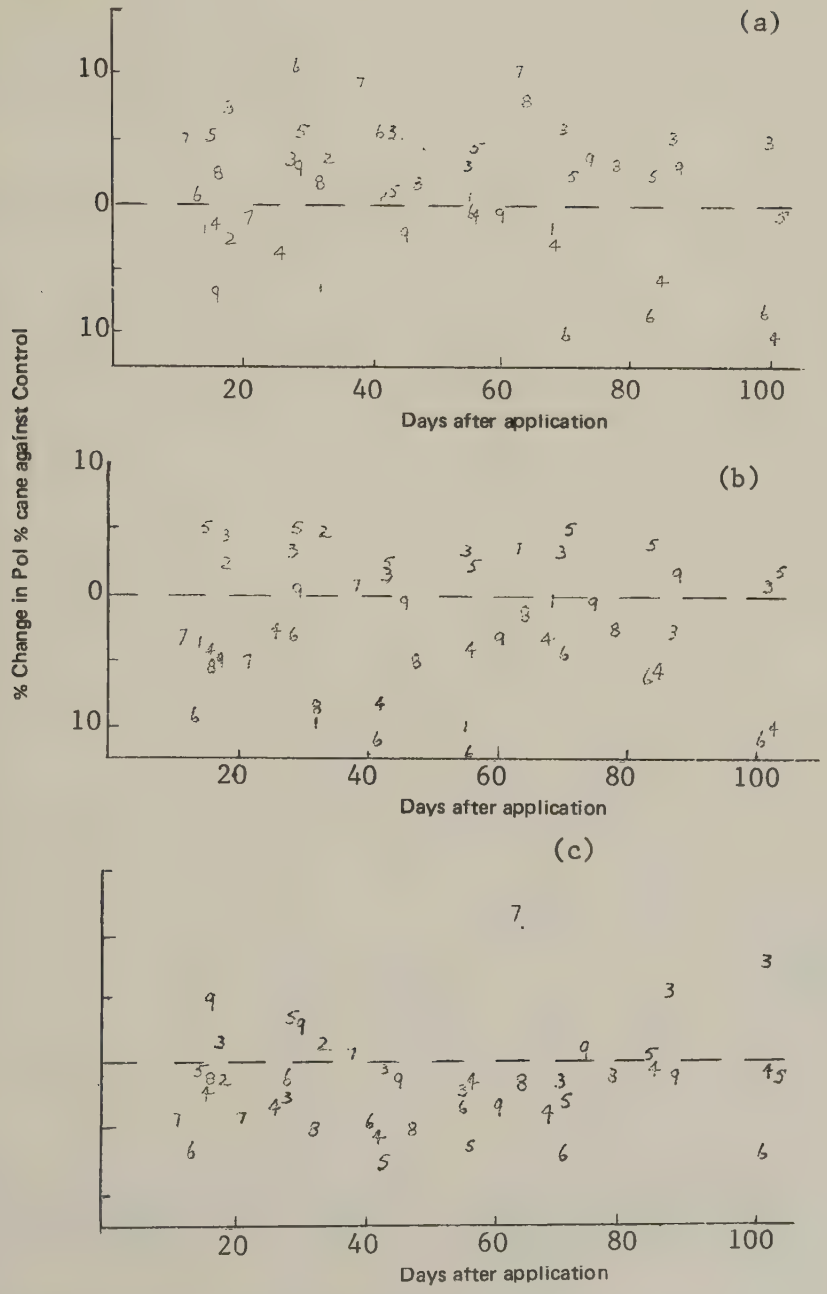
FIGURE 2. Per cent change in pol % cane relative to control with XHH 148 (a), Mon 8000 (b), and Mon 2139 (c).

than Ethrel and FR 600/1 since it gave marginal increases in pol % cane (not sig. P 1 0.05) of between 2 to 10% in the majority of samples. In trials 3, 5, 6, 7 and 8 on consecutive sampling dates, pol % cane levels were found to be consistently higher than controls. In the other trials, wide fluctuations occurred.

Juice Purity:

Embark, Ethrel, FR 600/1 and XHH 148 gave slight marginal increases (P = 0.05 not sig) in juice purity in the minority of trials, while significant increases (P = 0.05) were obtained with Mon 2139 in trial 5 and Mon 8000_a in trial 7, Mon 8000_b in trial 6 and Polaris in trials 5 and 6 (Table 4).

Similar significant improvements were also observed with those trials in which very large (over 15%) increases in pol % cane occurred. On the whole, variation in juice purity was generally low at less than 5% (CV ranged from 1.5 to 5%). This was



Numbers indicate that of the trial.
Numbers encircled are significant P = 0.05.

FIGURE 3. Per cent changes in pol % cane relative to control with Embark (a), Ethrel (b) and FR 600/1 (c).

TABLE 4. Juice purity changes relative to control in cane ripener trials.

Treatment	Trial No.								
	1	2	3	4	5	6	7	8	9
Embark-2-S	0	0	0	0	+	+	+	0	–
Ethrel	–	+	0	–	+	–	–	–	–
FR 600/1		0	0	0	0	0	+	0	0
Mon 2139	0	–	0	0	++				
Mon 8000_a						+	++	0	+
Mon 8000_b						++		0	0
Polaris	0	0	0	0	++	++	+	0	0
XHH 148	+	0	0	+	0				

Legend:
0 – similar to control
– – marginally lower than control
+ – marginally higher than control
++ – significantly higher than control.

TABLE 5. Mean percent cane weights relative to control due to the various ripeners.

Treatment	Mean % cane weight Trial No.						
	3	4	5	6	7	8	9
Control	100	100	100	100	100	100	100
Embark	88c	99	101	104	98	99	99
Ethrel	97	92	101	99	102	93	99
FR 600/1	101	101	99	101	96	86c	89c
Mon 2139	94	88c	91c	–	–	–	–
Mon 8000_a	–	–	–	109	108	90c	91c
Mon 8000_b	–	–	–	102	–	92c	97
Polaris	97	100	85c	103	100	113	90c
XHH 148_a	92	97	97	–	–	–	90c

c – cane weights were consistently lower than controls throughout the trial.

similar to that reported by Julien[5]. Marginal increases of 5% and less could not be determined statistically, even though such improvements in juice are more than welcome in commercial processing.

Cane weights:

Cane weights for trial 1 were obtained by harvesting all canes at the end of the trial. The results proved to be extremely variable and useless, and from trial 3 bundle weights were determined. Generally though, successive weights of 5-cane

TABLE 6. Moisture % cane at about 18 weeks and about 12 weeks in cane ripener trials.

Trial No.	1	2	3	4	5	6	7	8	9	
	Days after application									
Treatment	68	33	55	57	56	56	49	45	57	Mean
Control	71.72	70.40	72.99	72.33	70.47	71.62	70.81	67.07	70.19	70.84
Embark	71.99	70.75	72.42	72.47	70.29	71.99	69.95	66.16	69.60	70.62
Ethrel	71.49	70.60	72.82	73.19	70.33	73.75	70.61	67.97	70.62	71.44
FR 600/1	–	70.39	73.37	72.74	71.18	74.17	70.88	68.16	70.60	70.44
Mon 2139	71.04	71.04	70.99	72.08	68.25	–	–	–	–	70.75
Mon 8000_a	–	–	–	–	–	71.13	68.79*	65.76	68.44	68.53
Mon 800_b	–	–	–	–	–	69.62*	–	65.65	70.18	68.48
Polaris	71.46	71.93	72.42	71.07	67.02*	69.69'	70.76	66.98	70.17	70.17
XHH 148_a	71.02	70.44	71.43	71.09	71.28	–	–	–	–	71.29
XHH 148_b	70.75	–	–	–	–	–	–	–	–	70.75
LSD 5%	2.21	2.21	2.05	2.01	2.34	2.23	1.68		1.20	

	Days after application							
Treatment	88	103	013	100	69	76	85	Mean
Control	72.75	70.01	70.21	71.57	69.92	66.72	68.30	69.93
Embark	72.61	72.12	70.38	72.12	69.58	66.18	67.80	70.11
Ethrel	73.78	71.37	69.94	72.84	70.67	66.36	68.43	70.48
FR 600/1	73.07	70.78	70.12	71.28	68.91	66.27	67.87	69.77
Mon 2139	72.87	69.15	69.66	–	–	–	–	70.56
Mon 8000_a	–	–	–	72.31	69.61	66.78	67.94	69.16
Mon 8000_b	–	–	–	70.54	–	63.81	67.74	67.36
Polaris	72.98	70.73	69.44	70.71	68.11	66.84	67.80	69.52
XHH 148_a,	72.97	69.94	70.73	–	–	–	–	71.21
XHH 148_b	–	–	–	–	–	–	–	–
LSD 5%	1.63	1.87	1.12	1.14	–	–	4.34	

*1 = sig. P = 0.10 : * –Sig. P = 0.05.*

samples were variable to a lesser extent than in trial 1 with CV values ranging from 13 to 28% (mean was at 19%). This made it difficult to obtain statistical significance of mean difference in this range, as reported by Julien[5]. Most of the weight reductions were therefore not significant. The mean percent cane weight due to the various ripeners compared to the control are presented in Table 5. In certain instances, there were marginal but consistent reductions. These were with Embark in trial 3, FR 600/1 in trials 8 and 9, Mon 2139 in trials 4 and 5, Polaris in trials 5 and 9, Mon 8000_a in trials 8 and 9, and Mon 8000_b in trial 8. These consistent marginal reductions in cane weight cannot however, be considered as directly related to sucrose enhancement, since in some instances no enhancement occurred.

TABLE 7. Tillers per meter after ratooning in some cane ripener trials

Trial No.	1	2	5	7	8	9
			Weeks after harvest			
Treatment	24	24	8	6	7	7
Control	13	24	26	32	31	20
Embark-2-S	19	24	29	35	32	24
Ethrel	–	–	29	41	34	25
FR 600/1	–	27	26	35	30	20
Mon 2139	18	22	–	–	–	–
Mon 8000_a	–	–	30	47	21	23
Mon 8000_b	–	–	47	–	42	26
Polaris	17	24	28	40	32	20
XHH 148_a	17	26	–	–	–	–
XHH 148_b	13	–	–	–	–	–
LSD 5%	8	8	11	9		10

There were many instances however, where cane weight was unaffected despite the fact that there was sucrose enhancement. It is likely therefore, as suggested by Alexander[1], that the action of ripeners in bringing about sucrose enhancement may be unrelated to mechanisms affecting cane weight.

Moisture % cane:

All ripener treated cane had moisture % cane levels which were significantly different (P = 0.05) to that of untreated cane. However in trial 5, Mon 2139 and Polaris treated cane had consistently lower moisture % cane levels (significant P - 0.05). In trial 6, Mon 8000 and Polaris gave generally lower moisture % cane levels. Mean moisture % cane levels at the midpoint and at the end of the trials are presented in Table 6. A closer examination of all moisture % cane data showed that Mon 2139, Mon 8000, XHH 148 and Polaris treated canes have lower levels (not significant P = 0.05). It was also found that in most trials, moisture levels in untreated cane fell as the trials progressed. This is to be expected as a consequence of the reduction in soil moisture and the general progress of cane to full maturity. It seems therefore that desiccation due to the above mentioned ripeners was largely masked by the natural drying out.

Fiber % Cane:

There was no significant difference in fiber content as a result of any of the treatments compared to that of the untreated cane.

Ratoon regrowth:

Stalk counts were taken of ratoon regrowth for trials 1, 2, 6, 7, 8, and 9

(Table 7). From these results and general observations of the remaining trials, ratoon regrowth of cane ripener treated plots were similar to that of control plots.

CONCLUSIONS

Cane ripeners containing glyphosate were generally more effective than Polaris in bringing about sucrose enhancement in B 41227. However, on heavy textured soils where cane maturity is slow Polaris was just as effective as Mon 2139. Glyphosate type ripeners were also generally capable of faster initial responses and longer periods of enhanced sucrose levels than with Polaris. The Mon 2139 formulation of glyphosate seemed to be more effective than the other two, while XHH 148 seemed to be the least effective. There should however be some reservations in accepting this since Mon 8000 replaced Mon 2139 and XHH 149 in trials 6 to 9. Generally these findings were consistent with studies conducted in other countries (Eastwood[2], Hilton *et al*[3], Samuels and Alers[10]). FR 600/1 was ineffective. Embark and Ethrel only gave marginal improvement. In the case of the latter, sucrose enhancement was too rare such that it cannot be considered suitable to ripen B41227 in Trinidad.

Mon 2139, Mon 8000 and Polaris curtailed cane growth rate as is widely reported (Rostron[9], Alexander[1]). But since cane growth rate at this time is very slow the decreases were negligible.

With respect to moisture % cane, the larger ripening responses (sucrose enhancement) with Polaris, Mon 8000, Mon 2139 and XHH 148 seemed to be associated with marginal reduction in moisture. It seems, therefore, that the larger responses were in part due to desiccation, and the more modest ones (5 to 15%) were due to other physiology changes. Finally, juice purity was improved only where sucrose enhancement was large, but fiber content, cane weight and ratoon re-growth were not found to be affected by any action of cane ripeners.

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MADURACION QUIMICA DE LA VARIEDAD B 41227 EN TRINIDAD

George F. Mason

RESUMEN

Durante 1976-79 se condujeron en Trinidad, ensayos en micro-parcelas con maduradores quimicos con la variedad B 41227.

El objectivo fue seleccionar aquellos productos, que fueron mas capaces que el Polaris en aumentar el contenido de sacarosa en esta variedad por un largo periodo, a un grado maximo y bajo una amplia gama de condiciones.

Efectos colaterales adversos como ser, cese del crecimiento, reduccion del peso de las cañas, desecacion y pobre retoñamiento comunmente atribuidos al Polaris, fueron estudiados simultaneamente para todos los productos.

Los productos basados en glifosato, Mon 2139, XHH 148 y Mon 8000, fueron encontrados superiores al Polaris juzgando por el incremento del Pol % caña. El Embark 2-5 y Ethrel fueron menos efectivos que el Polaris, mientras que FR 600/1 fue considerado ser insensible bajo estas condiciones o con esta variedad. El cese de crecimiento, las reducciones en el peso de las cañas y la desecacion, fueron todos estos

factores, encontrados en pequeña medida en la mayoria de los maduradores, pero no siempre estuvieron asociados con una ganancia de sacarosa.

Las cañas sin tratar tambien sufrieron cambios similares, pero en grado limitado.

El rebrote de las socas no fue afectado adversamente por cualquier madurador.

RIPENING ACTIVITY OF THE GLYPHOSATE SALTS MON 8000 AND ROUNDUP

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ABSTRACT

The salts of glyphosate Mon 8000 (600 g ae per kg) and Roundup (359 g ae per liter) produced similar ripening responses when compared at 1.0 kg and 1.5 l ha^{-1} or 0.67 kg and 1.0 l ha^{-1} respectively.

The improvement in cane quality persisted for up to 20 weeks after application. However, increases in the mass of estimated recoverable sugar generally diminished from 6 weeks after spraying as a result of a reduction in stalk mass brought about by the inhibition of apical growth.

Results were obtained from 48 trials in which Mon 8000 or Roundup were applied to cane growing in the three main ecological regions of the sugar industry. Trials carried out during the growing period, between October and April, produced a mean increase of 1.5 units of sucrose resulting in a 14.4% increase in mass of estimated recoverable sugar. During the winter months from May to September appreciable and consistent responses were obtained in the hotter northern irrigated region while responses in the cooler coastal and midlands rainfed regions were generally poor and inconsistent.

The analyses of stalks divided into the lower and upper parts confirmed that the glyphosates were able to increase the sugar yield of mature actively growing sugarcane by loading sucrose into the lower and more mature parts of the stalk.

Measurements of regrowth of the subsequent ratoon crop showed that over application must be avoided and that the early signs of chlorosis, and stunting when it occurred tended to diminish with time.

INTRODUCTION

The salts of glyphosate, Mon 8000 and Roundup, were evaluated as early and late season chemical ripeners and compared with the registered ripeners Ethrel and Embark (Clowes[1]). There was evidence that all four chemicals ripened immature stalk early in the milling season. However, the glyphosates were able in addition to increase sucrose in or load sucrose into the lower parts of mature stalk. Consequently

the glyphosates were able to increase the yield of sucrose when applied to mature sugarcane with juice purities in excess of 80% at the time of spraying both early and late in the milling season.

The object of this paper is to describe the ripening effects of the glyphosates in more detail now that an additional 41 trials have been completed.

Trials were designed, mainly using variety NCO 376, to compare the effects of the two salts of glyphosate and to study the pattern of the responses to treatment with time. Results from a total of 48 trials have now been used to provide more detailed information on ripening responses in the three main ecological regions of the South African cane belt. In two of the trials, harvested stalks were partitioned before being analyzed so that the ripening effects of glyphosate on mature cane could be studied in detail. Finally some observations on regrowth of the subsequent ratoon crop are presented and discussed.

MATERIALS AND METHODS

Glyphosates were evaluated in 48 small plot trials which are classified according to ecological region and time of spraying in Table 1. The regions represented are:

(i) Northern irrigated area, comprising Pongola, Swaziland and the Eastern Transvaal, which is semi-arid and where irrigation is necessary for sugarcane crop production

(ii) Coastal area of Natal, where the crop is rainfed and grown at altitudes less than approximately 300 m.

(iii) Midlands area of Natal, where the crop is also rainfed and the altitude is generally greater than 300 m.

The season has been divided into two phases, a ripening and a growth phase. The ripening phase coincides with the cooler temperatures which are experienced from the beginning of the harvesting season in May until September, while the remaining warmer months from October until April constitute the growth phase. Cane can be harvested annually in the northern semi-arid irrigated regions where temperatures are highest. Along the coastal belt and in the midlands where temperatures are lower and few areas receive supplementary irrigation, cane is harvested at approximately 16 to 18 to 24 months of age respectively.

The sodium salt formulation of glyphosate, Mon 8000 (600 g acid equivalent (ae) per kilogram) was initially tested at 0.5 and 1.0 kilograms of product per hectare and subsequently a rate of 0.67 kg ha^{-1} product was used and adopted as a standard rate. Roundup (359 g ae per liter) was tested at comparable but not identical rates of acid equivalent. Initially 0.75, 1.0 and 1.5 liters of product were tested, but subsequently a rate of 1.0 liter of product per hectare was used and adopted as a standard rate.

TABLE 1. The distribution of 48 trials in three ecological regions

Ecological region	Number of trials	
	Ripening phase	Growth phase
Northern irrigated	5	4
Coastal	15	13
Midlands	8	3

The chemicals were applied in small plot trials to two rows of cane simultaneously, using an extended lance attached to a carbon dioxide pressurized sprayer. Two Spraying Systems TK 1.0 floodjets were positioned immediately above adjacent cane rows on a T-piece attached to the top of the lance. These delivered approximately 70 liters per hectare at a pressure of 200 kPa, moving at a pace between 1.1 to 1.4 m per second, depending upon the row spacing, which varied between 1.2 and 1.5 m. In the first four trials TK 2.5 nozzles were used and the volume of water applied varied between 400 and 800 l per hectare. Treatments were applied when weather conditions were favourable for spraying. There were two or three guard rows between net plots, which varied in area between 20 and 48 m^2.

Samples comprising a total of 16 randomly selected stalks per plot were taken from two adjacent positions within each row at the time of spraying and at various intervals thereafter. The trashed stalks were topped by hand at the natural breaking point. Each bundle of 16 stalks was fed through a disintegrator and sub-samples were analysed for juice quality and fiber content. The % of estimated recoverable sugar (ers % cane) was determined using the formula: ers % cane = sucrose % — 0.485 (non sucrose %) — 0.056 (fiber %).

On two occasions additional samples consisting of 24 stalks per plot were taken and each stalk was divided into the lower 0.75 m and the remainder. Each part was then processed and analyzed separately.

The effects of the glyphosate on the regeneration of the following untreated ratoon crops were assessed in a number of trials by measuring stalk height to the top visible dewlap. Twenty stalks were selected at random for measurement in each plot. Shoots, and subsequently stalks were counted and visual assessments of regrowth were made at intervals.

For convenience an independent and arbitrary system of numbering trials has been used in each section.

RESULTS

Comparing the two salts of glyphosate, Mon 8000 and Roundup.

Six of the 48 trials were conducted to compare Mon 8000 with Roundup.

TABLE 2. Increase in sucrose % cane after treatment with Mon 8000 and Roundup at different rates

Trial	Region	Age at time of spraying months	Variety	Month sprayed	Mon 8000		Roundup	
					Rate of product kg./ha	Increase in sucrose % cane	Rate of product l/ha	Increase in sucrose % cane
1	Coastal	14	NCo 376	March	1	0.6*	1.5	0.8*
2	N. irrigated	10	NCo 376	March	1	3.1*	1.5	2.7*
3	N. irrigated	8	NC0 376	Sept	1	2.4*	1.5	2.5*
		8	N52/219	Sept	1	2.1*	1.5	1.7*
4	Coastal	10	N55/805	Oct	0.67	1.6*	1.0	2.1*
5	Midlands	19	NCo 376	Oct	0.67	0.6	1.0	0.8
6	N. irrigated	8	NC0 376	July	1	1.8*	1.5	1.7*
		8	NCo 376	July	0.67	1.7*	1.0	1.7*
		8	N52/219	July	1	0.9*	1.5	1.3*
		8	N52/219	July	0.67	1.1*	1.0	1.0*
			Mean response			1.6		1.6

* *Statistically significant increase, P = 0.05*

TABLE 3. Details of the five trials designed to determine the persistence of ripening responses

Trial	Region	Variety	Month sprayed	Crop	At spraying		
					Age months	Estimated tons cane ha^{-1}	Juice purity %
1	Northern irrigated	NCo 376	March	2R	10	92	62
2	Midlands	NCo 293	March	3R	17	105	88
3	Coastal	NCo 376	April	3R	8	71	70
4	Coastal	N55/805	October	P	11	95	91
5	Coastal	NCo 310	January	2R	14	82	92

TABLE 4. Results obtained 3-6 weeks after spraying nine trials conducted in the northern irrigated region

Phase	Variety	Age	Month sprayed	Difference from control		% Response			
				Sucrose % cane	Juice purity	Cane mass	Dry mass	Mass sucrose	Mass Mass Ers
Growth	NCo 376	10 m	March	3.3*	9.8*	- 8.6	4.1	24.5	39.8
Growth	NCo 376	11 m	March	2.1	6.9*	- 3.0	4.2	20.0	30.8
Growth	NC0 376	12 m	Jan	0.6	2.5	0.9	11.7	6.6	7.4
Growth	NCo 376	10 m	Jan	0.8	0.4	11.3	16.6	20.7	21.7
Growth	N52/219	11 m	Feb	1.2*	2.5	- 4.0	2.3	9.8	14.0
	Mean			1.6	4.4	- 0.7	7.8	16.3	22.7
Ripening	NCo 376	8 m	July	2.0*	3.1*	- 0.1	7.5	16.8	20.4
Ripening	N52/219	8 m	July	1.0*	0.8	1.5	4.7	9.7	10.8
Ripening	NCo 376	8 m	Sept	3.0	5.1*	-16.0	- 4.0	5.1	9.8
Ripening	N52/219	8 m	Sept	2.4*	3.8*	-10.8	0.7	9.7	8.3
	Mean			2.1	3.2	6.4	2.2	10.3	12.3

** Statistically significant difference, P = 0.05*

Details of the trials and rates used are shown in Table 2.

The responses at 3, 6 and 9 weeks after spraying were averaged and the increases in sucrose % cane compared with the control plots are given in Table 2. The results show that the ripening responses in terms of sucrose % cane were similar for the products at both the high and low rates tested. The two chemicals produced a statistically significant (P = 0.05) increase in sucrose % cane in five out of the six trials.

Persistence of the response

Five trials were carried out with the object of determining the persistence of the response under different conditions. Details of the five trials are given in Table 3 and ripening responses are shown in Fig. 1, 2 and 3. All five trials produced statistically significant ripening reponses with increases in sucrose % cane of approximately two percentage units (Figure 1). The improvement in cane quality persisted for at least 12 weeks after spraying. However, inhibition of apical growth tended to reduce stalk mass (Figure 2) from about six weeks after spraying onwards resulting in the greatest sucrose yield increases being obtained approximately six weeks after spraying (Figure 3).

Results from 48 trials

The evidence presented in Figures 1, 2 and 3 indicates that responses are likely to be greatest approximately six weeks after spraying and that Mon 8000 and Roundup produce similar ripening effects at the rates tested. Consequently data from the 48 trials with Roundup or Mon 8000 were combined and classified according to region, and then sub-divided within each region into the ripening (May to September) and growth (October to April) phases. The results are presented in Tables 4, 5 and 6. The interval between spraying and sampling varied between 3 and 6 weeks with a mean interval of 5,3 weeks (stand deviation 0.85). Results from each of the regions are discussed separately.

Northern irrigated region

Results from the nine trials, five of which were carried out during the growth period and four during the ripening period are presented in Table 4. Good ripening responses were obtained during both the growth and ripening phases with varieties NCo 376 and N52/219. There is evidence to suggest that stalk drv matter may have been increased slightly as a result of treatment.

The mean percentage increase in yield from all nine trials was 13% and 18% respectively for sucrose and estimated recoverable sugar. The greater percentage response in estimated recoverable sugar was largely due to the increase in juice purity resulting from treatment with glyphosate.

Coastal Region

Twenty eight trials were conducted in this region, with the majority being carried out during the growth phase. All of the 15 trials conducted during the growth phase produced significant ripening responses whereas responses during the cooler ripening phase were inconsistent and tended to be small (Table 5).

Trials carried out during the growth phase increased the yields of sucrose and estimated recoverable sugar by respectively 8% and 10%.

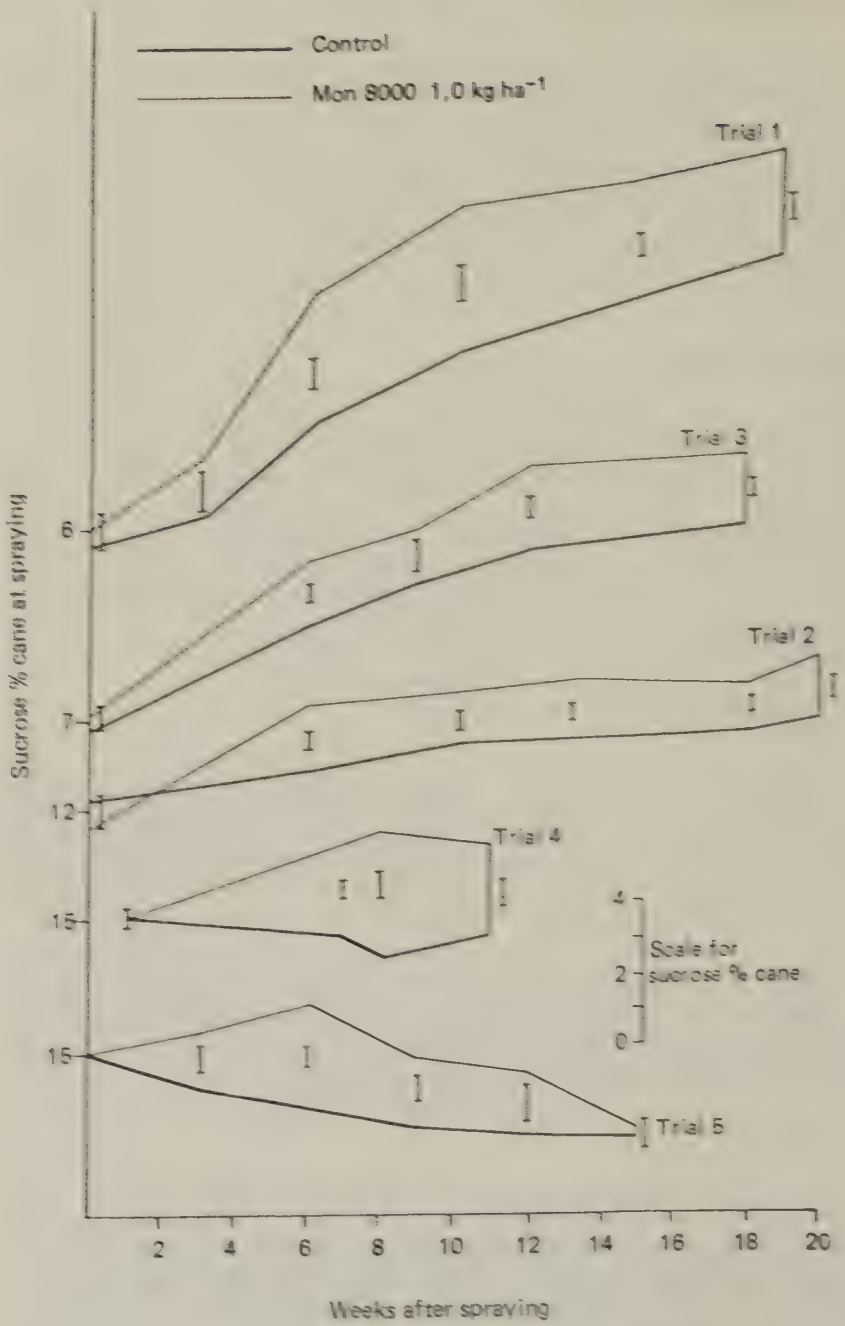

FIGURE 1. The increase in sucrose % cane from applying 1.0 kg ha^{-1} of Mon 8000. LSD (P = 0.05) values are indicated.

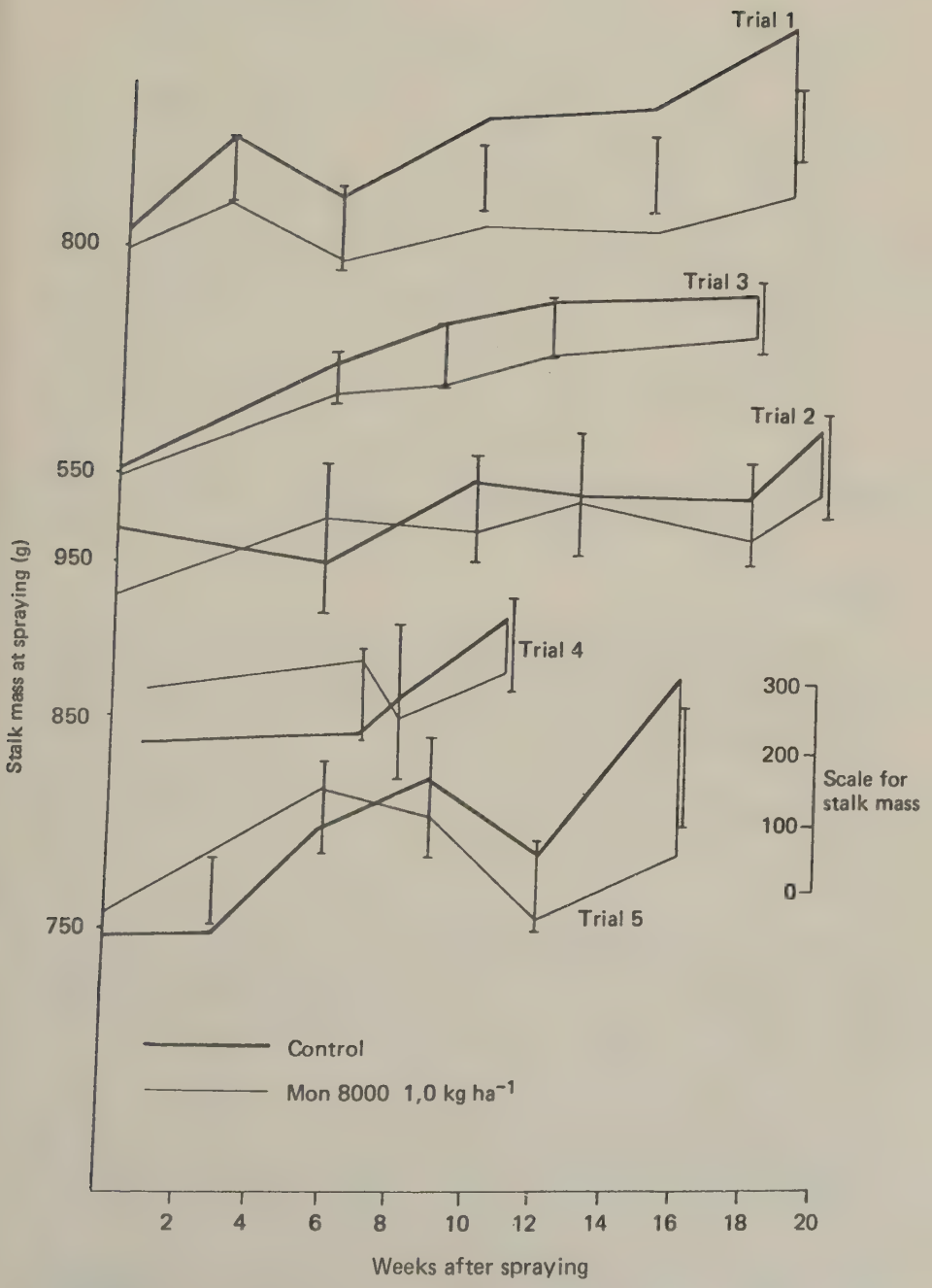

FIGURE 2. The effect on stalk mass from applying 1.0 kg ha^{-1} of Mon 8000. LSD (P = 0.05) values are indicated.

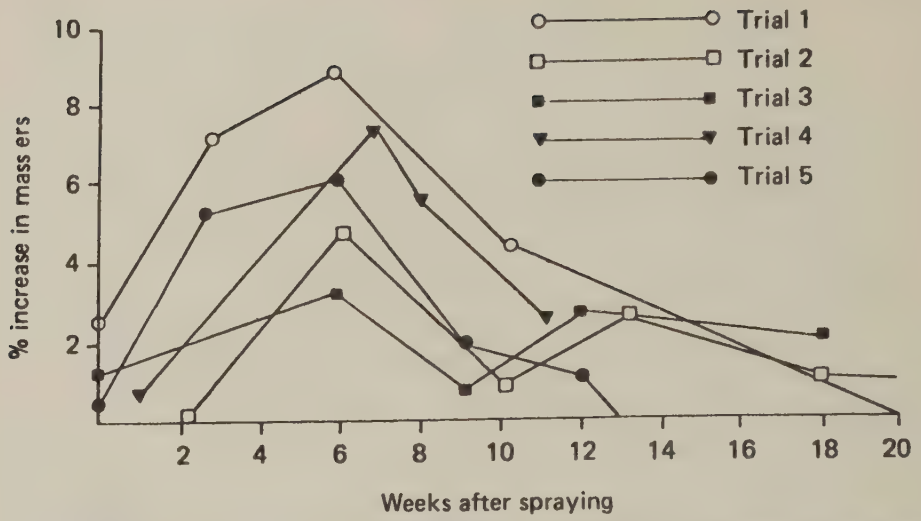

FIGURE 3. The increase (as a percentage) in the mass of estimated recoverable sugar from applying 1.0 kg ha^{-1} Mon 8000

Midlands region

Ripening responses during the growth phase attained a level of statistical significance in six out of eight trials and there was some evidence of a response in the other two trials. In contrast, no responses were obtained in the three trials carried out during the ripening phase (Table 6).

Trials carried out during the growth phase increased the yield of sucrose and estimated recoverable sugar by 8% and 10% respectively.

Partitioning

In two trials mature cane with a juice purity of approximately 90% was used to obtain additional information on the ripening effects of glyphosate. For analysis stalks were divided into two parts, the lower 0.75 m and the remainder, and the results are shown in Tables 7 and 8. Treatment with a glyphosate significantly improved cane quality in both the lower and upper portions of the stalk.

The improvement in cane quality was greater in the top than the bottom portion of the stalk. However, the greater stalk mass of the lower portion of stalk resulted in a significant increase in sucrose yield being obtained from its portion of stalk. This increase in sucrose yield in the bottom portion of the stalk resulted from an increase in sucrose % cane without an increase in juice purity. The term 'sucrose loading' has been used (Clowes[1]) to describe this process of sucrose accumulation. There is some evidence that the ripening effect in the top portion of treated stalk in the coastal region (Table 7) was offset by the lower stalk mass resulting from the inhibition of apical growth. However, in the trial in the midlands

TABLE 5. Results obtained 3-6 weeks after spraying the 28 trials conducted in the coastal region

Phase	Variety	Age	Month sprayed	Difference from control			% Response		
				Sucrose % cane	Juice purity	Cane mass	Dry mass	Mass sucrose	Mass Ers
Growth	NCo 376	14 m	March	1.9*	3.5*	−20.0	−13.2	−8.4	− 5.8
Growth	NCo 376	14 m	March	1.8*	2.6	− 6.8	− 4.5	−0.9	− 0.8
Growth	NCo 376	8 m	April	1.7*	4.6*	− 5.3	0.3	11.0	15.7
Growth	N55/805	10 m	Oct	1.9*	3.4*	2.5	12.8	16.8	19.6
Growth	N55/805	11 m	Oct	2.5*	3.6*	0.3	8.3	18.4	18.3
Growth	NCo 376	12 m	Oct	1.2*	−0.5	1.8	7.8	10.9	11.0
Growth	NCo 376	13 m	Oct	1.9*	1.2	3.5	4.2	10.0	11.5
Growth	N55/805	11 m	Nov	1.8*	2.8*	− 3.3	1.4	9.3	12.2
Growth	NCo 376	13 m	Nov	1.8*	2.4*	4.1	11.1	19.7	22.4
Growth	NCo 376	18 m	Nov	2.1*	2.8*	11.2	19.7	30.5	34.0
Growth	NCo 376	12 m	Dec	1.6*	1.3	−4.9	2.5	5.6	6.7
Growth	NCo 376	13 m	Dec	0.9*	−0.7	−12.6	− 8.6	− 7.0	−7.1
Growth	NCo 376	12 m	Jan	2.5*	3.2*	−24.4	−15.3	− 8.2	− 5.6
Growth	NCo 376	13 m	Jan	1.2*	2.0	2.9	7.7	11.5	13.2
Growth	NCo 310	14 m	Jan	1.5*	3.0*	− 8.4	1.2	8.9	11.6
		Mean		1.8	2.3	− 4.4	2.3	8.5	10.5
Ripening	NCo 376	10 m	May	0.2	−0.3	−13.0	− 8.6	−11.7	−12.3
Ripening	NCo 376	9 m	May	−0.4	−2.8*	6.4	3.8	3.2	1.3
Ripening	NCo 376	15 m	May	−0.2	−1.4	9.3	9.4	8.2	7.1
Ripening	NCo 376	11 m	June	1.1*	0.8	0.7	3.0	10.1	11.9
Ripening	NCo 376	11 m	June	−0.2	0.7	0.6	1.7	− 0.8	− 0.8
Ripening	NCo 376	18 m	June	−0.5	−3.9	− 3.4	− 3.1	− 6.6	− 9.1
Ripening	NCo 376	13 m	June	−0.7	−7.2	11.8	9.6	6.3	0.7
Ripening	NCo 376	10 m	July	0.3	0.4	5.7	8.6	7.5	7.4
Ripening	N55/805	11 m	July	0.0	0.1	−10.7	−11.5	−10.6	−10.4
Ripening	NCo 376	14 m	Aug	0.6*	0.4	0.6	4.8	4.7	5.0
Ripening	N55/805	12 m	Aug	1.3*	1.7*	−14.1	− 9.9	− 6.8	− 5.5
Ripening	NCo 376	14 m	Sept	1.0	0.9	− 8.4	− 5.0	− 2.6	− 1.8
Ripening	NCo 376	13 m	Sept	1.3*	1.5	4.7	7.7	14.2	16.0
		Mean		0.3	−0.7	− 0.8	0.8	1.2	0.7

Statistically significant difference P = 0.05

(Table 8) the mass of the top portion of stalk was not reduced by treatment with glyphosate. This treatment had however, affected apical growth as there was no natural breaking point and lateral buds had developed to form sideshoots.

In both trials fiber % cane was increased due to treatment with glyphosate in the top portion of the stalk by 1.4 to 2.0 percentage units, but there was a smaller, inconsistent effect in the lower portion of stalk.

Regrowth

Leaf chlorosis and stunting of growth in the subsequent ratoon crop when

TABLE 6. Results obtained 3-6 weeks after spraying the 11 trials conducted in the midlands region

Phase	Variety	Age	Month sprayed	Difference from control		% Response			
				Sucrose % cane	Juice Purity %	Cane mass	Dry mass	Mass sucrose	Mass Ers
Growth	NCo 293	17 m	March	1.5*	2.6*	4.8	9.6	16.6	19.8
Growth	NCo 376	17 m	March	1.4*	1.4	−5.3	−0.2	5.9	7.7
Growth	NCo 293	17 m	March	0.9	1.1	−9.9	−7.0	−3.5	− 2.5
Growth	NCo 293	15 m	Oct	0.5	1.0	−2.7	1.9	1.2	1.8
Growth	NCo 376	19 m	Oct	1.5*	2.3*	−1.5	5.6	10.0	12.1
Growth	NCo 376	12 m	Nov	2.3*	4.5*	−4.6	7.2	14.8	19.0
Growth	NCo 376	12 m	Jan	0.7*	1.7	2.4	4.8	9.0	11.0
Growth	NCo 293	16 m	Jan	1.2*	2.3*	−0.3	6.9	8.7	10.4
		Mean		1.2	2.1	−2.1	3.6	7.8	9.9
Ripening	NCo 376	14 m	May	−0.1	0.2	−3.1	−1.6	− 4.3	− 4.7
Ripening	NCo 376	16 m	July	0.3	−0.1	−0.8	0.7	2.0	2.2
Ripening	NCo 293	21 m	May	−0.2	−0.4	−4.9	−5.9	− 6.4	− 6.7
		Mean		0.0	−0.1	−2.9	−2.3	− 2.9	− 3.1

** Statistically significant difference, P = 0.05*

glyphosate at rates greater than 0.9 kg ai per hectare had been applied to the previous crop, have been reported by Clowes[1]. Consequently regeneration of the ratoon crops was carefully monitored in all the subsequent experiments, particularly those which were harvested at the optimum time between 4 and 9 weeks after spraying.

Northern irrigated region

In a trial where good ripening responses had been obtained from applying glyphosates in March, only the double rates of Mon 8000 (2 x 0.67 kg ha^{-1}) and Roundup (2 x 1.0 l ha^{-1}) caused early signs of chlorosis and slower initial growth of the subsequent ratoon and these effects were temporary.

In another trial the previous crop was harvested nine weeks after spraying the cane in July with different rates of Mon 8000 and Roundup. Measurements on the regrowth of the following untreated ratoon crop were taken 17 and 20 weeks after harvesting (Table 9). When all the glyphosate treatment effects were averaged there was a 4% reduction in stalk height, which was statistically significant, but stalk populations were not affected. No further measurements were obtainable because of lodging and the crop has yet to be harvested.

In trials harvested later than 12 weeks after spraying the regrowth showed some chlorosis but no evidence of early stunting.

TABLE 7. Coastal region. Partitioning data obtained nine weeks after spraying 10 month old N55/805 with a juice purity of 89% at time of spraying in October

Part of stalk	Treatment	Sucrose % cane	Fibre % cane	Juice purity	g/stalk				
					Fresh mass	Dry mass	Brix	Sucrose	Ers
Top	Control	11.9	13.0	84.3	487	131.5	68.5	57.8	49.0
	Mon 8000 0.67 kg	14.6	14.4	91.9	406	122.9	64.6	59.3	53.4
	LSD (P = 0.05)	1.08	—	4.23	91.1	—	—	9.17	8.55
	CV %	5.5	—	3.1	11.1	—	—	9.3	10.1
Bottom 0.75 m	Control	15.7	13.8	93.7	327	99.8	54.6	51.2	46.9
	Mon 8000 0.67 kg	17.0	13.3	94.7	342	106.8	61.4	58.1	53.9
	LSD (P = 0.05)	0.78	—	1.31	23.8	—	—	4.52	4.42
	CV %	3.1	—	0.9	4.4	—	—	5.3	5.6

TABLE 8. Midlands region: Partitioning data obtained nine weeks after spraying 16 month old NCo 293 with a juice purity of 91.5% at time of spraying inJanuary

Part of stalk	Treatment	Sucrose % cane	Fibre % cane	Juice purity	g/stalk				
					Fresh mass	Dry mass	Brix	Sucrose	Ers
Top	Control	10.6	10.5	83.1	496	115.2	63.1	52.4	44.3
	Roundup 1.0L	15.3	12.0	92.9	417	118.2	68.3	63.4	58.2
	LSD (P = 0.05)	1.02	—	3.56	86.9	—	—	11.2	10.4
	CV %	5.6	—	2.7	11.6	—	—	12.7	13.5
Bottom 0.75 m	Control	15.2	12.1	95.8	386	108.0	61.2	58.6	54.7
	Roundup 1.0L	16.6	12.7	95.8	390	117.0	67.4	64.6	60.4
	LSD (P = 0.05)	0.60	—	1.16	30.3	—	—	5.28	5.01
	CV %	2.5	—	0.8	5.3	—	—	5.9	6.0

TABLE 9. Stalk heights and populations of the following ratoon crop 17 and 20 weeks after harvest

Treatment applied to previous crop	Stalk height, m				Population $ha^{-1} \times 10^{-3}$			
	NCo 376		N52/219		NCo 376		N52/219	
	17	20	17	20	17	20	17	20
Control	1.25	1.71	1.25	1.66	182	196	135	143
Mon 8000 1.67 kg ha^{-1}	1.24	1.61	1.19	1.65	182	192	142	144
Roundup 1.0 l ha^{-1}	1.17	1.62	1.19	1.60	183	190	142	144
Mon 8000 3.7 kg ha^{-1}	1.12	1.61	1.14	1.61	183	186	137	143
Roundup 2.5 l ha^{-1}	1.21	1.67	1.13	1.58	179	191	135	142

NS. Significant differences ($P = 0.05$) to the control treatment are in bold type (underlined)

Coastal region

Most of the measurements on regrowth have been made in this region. In two experiments, irrigated NCo 376 was sprayed with 1.0 or 2.0 kg ha^{-1} of Mon 8000 and harvested on September 8, 19 weeks after treatment with 1.0 kg of Mn 8000 and 10 weeks after treatment with 2.0 kg of Mon 8000. The yields of the following untreated ratoon crops were obtained so that the residual effects of Mon 8000 could be assessed. The yields are shown in Tables 10 and 11. The higher rate of Mon 8000 significantly reduced cane yield and the yield of estimated recoverable sugar, whereas the lower rate of 1.0 kg ha^{-1} did not have a statistically significant effect.

Besides the results obtained under irrigated conditions, further data were recorded after harvesting cane grown under rainfed conditions, and which had been sprayed with 1.0 or 2.0 ha^{-1} of Roundup between May and December. The cane in all of these trials was harvested between 4 and 6 weeks after spraying. The results showed that the application of Roundup can result in early suppression of growth in the following untreated ratoon crop. Initial stalk height differences tended to decrease with time and the initially lower populations in the treated plots tended to increase and surpass those of the untreated control plots before finally stabilizing at levels similar to those of the unsprayed cane.

Similar results were obtained in the presence and absence of a trash blanket, except in the one trial sprayed in December, when trash may have further suppressed regrowth.

There was no visual sign of chlorosis or early stunting in two trials with

TABLE 10. Harvest results from an untreated ratoon crop following ripener application to the previous crop which was harvested 19 weeks after spraying in April

Treatments	Tons cane ha^{-1}	Ers % cane	Tons ers ha^{-1}	Population $\times 10^{-1}$
Control	112	10.8	12.1	169
Mon 8000 1 kg/ha	107	11.3	12.1	167
Mon 8000 2 kg/ha	100	11.1	11.1	169
LSD (P = 0.05)	5.23	0.54	0.66	5.94
CV %	5.8	6.6	7.6	4.9

NB. Harvest results from an untreated ratoon crop following ripener application to the previous crop which was harvested 10 weeks after spraying in June.

TABLE 11. Harvest results from an untreated ratoon crop following ripener application to the previous crop which was harvested 10 weeks after spraying in June.

Treatments	Tons cane ha^{-1}	Ers % cane	Tons ers ha^{-1}	Population $\times 10^{-1}$
Control	105	11.0	11.5	156
Mon 8000 1 kg/ha	101	10.6	10.7	156
LSD (P = 0.05)	22	1.3	1.6	26
CV %	9.6	5.3	6.2	7.5

TABLE 12. Stalk heights (m) and populations ($\times 10^{-3}$) of the following ratoon crops of NCo 376 which had been sprayed in May, July or October and harvested two to two and a half months later

Treatment	Parameter	Sprayed					
		May		July		October	
	Age	3m	8m	3m	5m	3m	5m
Control	Height	0.12	1.37	0.26	0.97	0.27	0.84
	Population	147	120	293	148	292	137
Mon 8000	Height	0.11	1.37	0.29	1.06	0.26	0.82
1 kg ha^{-1}	Population	141	126	303	158	312	142
Roundup	Height	0.11	1.34	0.28	0.97	0.26	0.83
1.0 l ha^{-1}	Population	146	113	286	143	302	135

variety N55/805 growing on a fertile alluvium soil. The cane was sprayed in October or November and harvested 9 and 6 weeks later respectively.

Midlands region

There was some evidence of chlorosis but no sign of stunting in the regrowth of cane in three trials sprayed with Mon 8000 (0.67 kg ha^{-1}) and Roundup (1.0 ha^{-1}) in May, July or October and harvested 2 to 2½ months later. Measurements of regrowth on the two and four month old ratoon crops confirmed that there were no residual effects of treatments (Table 12).

DISCUSSION

The results given in Table 2 show that the glyphosates Mon 8000 and Roundup produced similar ripening responses at the rates tested. The optimum rates for Mon 8000 (600 g kg^{-1} ae) and Roundup (359 gl. $^{-1}$ ae) are considered to be respectively 0.67 kg and 1.0 l of product per hectare. The rate of 0.67 kg ha^{-1} is comparable with the rate of 0.5 kg ai $acre^{-1}$ used by Eastwood[2] in Jamaica and 0.56 kg ha^{-1} of glyphosate used by Osgood[5] in Hawaii.

The most consistent responses were obtained six weeks after application (Fig. 1, 2 and 3). The improvement in cane quality persisted for as long as 20 weeks after spraying. However, the mass of estimated recoverable sugar tended to decrease from about 6 to 8 weeks after application as a result of the inhibition of apical growth.

Results from the 48 trials which were combined for analyses showed that good ripening responses were obtained during the main growing period between October and April. During this period the average increase of 1.5 units of sucrose and 2.9 percentage units of juice purity resulted in an increase in the mass of estimated recoverable sugar of 14.4%. If glyphosate were to be registered as a ripener at the current cost of Roundup, the treatment would be economically warranted. In southern Africa an investment of 30 Rand (approximately 36 U.S. dollars) per hectare, which includes application costs, would bring an additional return of approximately 140 Rand on a crop of 100 tons cane per hectare. This would be equivalent to a return on investment of over 450%.

Results of applications made during the cooler winter period from May to September showed that reasonable responses were obtained in the northern irrigated region. However, results from the cooler rainfed coastal and midlands regions indicated that glyphosates are not likely to improve on the natural ripening that occurs during the cooler and drier ripening phase in these areas.

Good ripening responses have been obtained from treating varieties NCo 376, NCo 310, N55/805, NCo 293 and N52/219 provided the cane was actively growing at the time of application.

The short interval of about six weeks between spraying and obtaining the

optimum response has both advantages and disadvantages. An advantage under rainfed conditions is that a response may be predicted provided the cane is actively growing when treated, and that there is sufficient moisture in the soil at spraying to satisfy the needs of the crop for at least a few weeks after the application of ripener has been made. A disadvantage is that if harvesting is not carried out in good time, yields will be reduced because of a decline in cane mass.

Partitioning results confirmed earlier findings (Clowes[1]) that, in addition to ripening immature stalk, the glyphosates were able to load sucrose into mature portions of the stalk. The good responses obtained from treating actively growing mature sugarcane with a juice purity of approximately 90%, result largely from the ability of the glyphosates to load sucrose into mature portions of the stalk.

These results obtained with glyposates, and recent unpublished results which show that the application of Ethrel to mature sugarcane can stimulate growth, suggest that the screening of chemicals should be carried out on both mature and immature sugarcane.

The ability of the glyphosates to ripen actively growing sugarcane through out the season in the northern irrigated region and at the end of the season in the other two regions suggests there may be prospects for promoting growth before applying a chemical ripener. Gibberellic acid is already being used commercially in Hawaii to overcome the limitations on growth of the cooler temperatures (Moore and Buren[4]). The prospects for using Ethrel and lower rates of glyphosates (Maretzki *et al*[3]) to promote growth before applying a ripener warrant testing under South African conditions. It may also be desirable to alter current fertilizer and irrigation practices to increase cane yields and then improve cane quality with a chemical ripener.

Numerous observations and data collected to date show that the application of glyphosates is not likely to have a marked effect on the yield of the following ratoon crop. Over-application must, however, be avoided and the cane should be actively growing at the time of application. Early signs of chlorosis and stunting which may occur when the currently-adopted standard rates are applied tend to diminish with time.

There is some evidence to suggest that increasing the interval between spraying and harvesting may reduce the effects of the glyphosates on the regrowth of the following ratoon. However, over-application is likely to be the most common cause of chlorosis or stunting of regrowth.

CONCLUSIONS

1. Mon 8000 (600 g ae kg^{-1}) and Roundup (359 g ae per liter) are equally effective as chemical ripeners and satisfactory rates appear to be 0.67 kg and 1.0 l. ha^{-1} respectively.

2. The improvement in cane quality persists for up to 20 weeks after treatment.

However, harvesting should be carried out about 6 weeks after application to ensure that reponses are not lost due to a reduction in stalk mass which results from the inhibition of apical growth following treatment.

3. Actively growing sugarcane treated between October and April in all three ecological regions of the South African cane belt is likely to respond and produce a mean increase in yield of approximately 14% in terms of estimated recoverable sugar, or an increase of approximately 1.5 units of sucrose.

4. Only cane in the warmer northern irrigated region is likely to produce consistent ripening responses when treated during the winter period from May to September.

5. Glyphosates increase the sugar yield of mature sugarcane by loading sucrose into the more mature lower parts of the stalk, besides having an effect on the immature tops.

6. The effects of the glyphosates on the growth of the following ratoon crop may be variable. However, provided the correct rate is applied to actively growing sugarcane the effects on the yield of the following crop are usually negligible. Signs of chlorosis and early stunting in the following ratoon crop may nevertheless be severe. Chlorosis disappears within a few months and at the canopy stage there has been no visual evidence of the early suppression of growth.

7. Delaying the harvest of treated cane longer than 9 weeks may reduce the effects of these chemicals on regrowth, however, it is not generally desirable to harvest treated cane later than about nine weeks after application.

8. The yield increase due to applying a glyphosate expressed as a percentage was greater for estimated recoverable sugar than for sucrose largely because of the improvement in juice purity.

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ACTIVIDAD MADURADORA DE LAS SALES GLIFOSATO, MON 8000 Y ROUNDUP

M. St. J. Clowes

RESUMEN

Las sales del glyfosato Mon 8000 (600 gr. i.a. por Kg) y Roundup (359 gr. ia. por litro) produjeron similares respuestas a la maduracion de la caña de azucar, cuando se compararon a las cantidades de un Kg y 1.5 litro/ha^{-1} o bien 0.67 Kg y 1.0 1/ha^{-1} respectivamente.

La mejora en la calidad de la caña persistio por mas de 20 semanas despues de la aplicacion.

Asimismo los incrementos en el conjunto del azucar recuperable estimado (ERS), generalmente disminuyeron desde las 6 semanas luego de la pulverizacion, como resultado de la reducion en la masa de tallos causado por la inhibicion del crecimiento apical.

Los resultados fueron obtenidos de 48 ensayos, en los cuales Mon 8000 o Roundup fueron aplicados a caña en crecimiento en las tres principales regiones ecológicas del área azúcarera.

Estos ensayos fueron conducidos durante el periodo de crecimiento, entre Octubre y Abril, produciendo un incremento promedio de 1.5 unidades de sacarosa, resultando un 14.4% de incremento en la masa del ERS. Durante los meses de invierno desde Mayo a Setiembre, hubo una respuesta apreciable y consistente en la region noreste (Cálida e irrigada), mientras que en la zona costal mas fresca y en las regiones mediterraneas lluviosas, la respuesta fue por lo general, pobre e inconsistente.

Los analisis de tallos divididos en las partes bajas y superiores, confirman que el glyfosato es capaz de incrementar el rendimiento de azucar en la parte madura del crecimiento activo por volcar la sacarosa en las partes bajas y mas maduras del tallo.

Las medidas del rebrote de las socas subsiguientes, mostraron que las sobra aplicaciones deben ser evitadas, y que los signos iniciales de clorosis y enanismo- cuando ocurren- tienden a disminuir con el tiempo.

EFFECT OF GLYPHOSATE RIPENER ON GROWTH RESPONSE AND SUGAR YIELD OF SUGARCANE

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ABSTRACT

Two small plot field trials were conducted in Victorias, Negros to evaluate the effect of glyphosate ripener as the Mon 2139 formulation using full test analysis of stalks partitioned from the top downward and by expressing results on a per cane basis.

There was an average increase of 26% in grams sucrose per stalk with 0.3 kg ai/ha Mon 2139 with relatively mature 8-mo. old variety Phil 56-226 at spraying 6 weeks before harvest. Sugar increase was not accompanied by a reduction in the weight per stalk. Spraying immature 8-mo. old cane of the same variety 8 weeks before harvest with 0.6 kg ai/ha resulted in a 21% increase in sucrose per stalk. This increase would have been higher had the stalk weight not been reduced by 4%.

Partitioning of stalks showed that while increases in pol % case or sucrose % dry matter were greatest in the top portion (internodes 7-15), the bottom section can account for a large part (30-70% of the sucrose increase because of the bigger weight of this portion and by a process of "loading" whereby sucrose accumulates even in the more mature parts of the stalk. This storage of sucrose is paralleled by an actual increase in total dissolved solids with little or no increase in juice purity.

There was no adverse effect on ratoon germination, tillering, and height with 0.3 kg ai/ha Mon 2139 in one site and regrowth is not expected to be a problem in the other location because there was little or no reduction in the stalk weight and length of the plant crop at this rate. The effects of glyphosate on ratoon regrowth and sugar yield require further study.

INTRODUCTION

Glyphosate ripeners were found in a previous study in Victorias, Negros to give a significant increase in piculs sugar per ton cane or PS/TC (juice quality) of about 15% were variety Phil 56-226 (Gonzales and Tianco[7]). However, the cane tonnages of treated plots that gave a good response were lower by about 5% com-

pared to the control. Maretzki *et al*[9] have observed both simulation and retardation of young internodes of a 20-mo old crop treated with glyphosate depending on the concentration applied. The critical concentration for these responses appeared to be between 1.0 and 3.0 mg glyphosate per stalk applied to 6-mo old plants. There was a need therefore to define better the optimum rate of glyphosate which would give a good response without significantly affecting the cane tonnage. According to Julien[8], variation of fresh weight yield per plot was the main problem encountered in field testing of ripeners. The variation was reduced by expressing results on a fresh weight per cane basis.

Studies by Clowes[4] in South Africa with Mon 8000 and Roundup have shown a rapid ripening response 3-6 weeks after spraying. However, both chemicals tended to reduce stalk mass (weight) because of inhibition of apical growth soon after spraying and there was a need to harvest the crop as soon as possible after the response. The analysis of stalks partitioned from the base either Mon 8000 or Roundup is due in large part to sucrose accumulation in the more mature parts of the stalk (Anon[2]).

Investigators at the HSPA Expt.Sta.in Hawaii have sampled the upper 15 internodes where the greatest changes in refractometer solids and pol occur (Coleman[5]). The present study aims to determine the effects of glyphosate on the different top sections of the stalk by partitioning from the top downward after cutting and topping.

The three rates of glyphosate used in this paper were based on the results of our previous study. Sampling at different times after spraying would give an indication of the optimum time for harvesting.

MATERIALS AND METHODS

Two small plot field tests with five replications each were conducted from November 1978 to February 1979 in two locations in Hda. Bilbao and Hda. Sta Barbara in Northern Negros using a knapsack sprayer for applying the chemical ripener. Both experiments were carried out on plant cane of variety Phil 56-226 which is a high-sucrose early-maturing cane. Age at spraying was about 8 months. Treatments applied were glyphosate or Mon 2139 (isopropylamine salt of N-phosphonomethyl glycine at 0.3, 0.6 and 0.9 kg ai/ha and glyphosine or Polaris (N-N-bis (phosphonomethyl) glycine) at 6 kg product/ha as standard. Each plot measured 5 rows x 10 m. Effects of spray drift between plots were largely eliminated by sampling only from the center three rows and at least 1.5 m inside the plot.

Total volume of spray solution in water was 3.1 l. per lot equivalent to about 600 1 per hectare. The spray was applied one meter above the cane canopy at 25 psi through an 8004 T-jet nozzle mounted on a long lance. Volume of spray required two passes. Spraying was started at about 0900 hours and completed by about 1100 hours.

Ten stalks sample from the center 3 row x 7 m of each plot were taken at

random before spraying and at 2, 4, and 6 weeks after application in the Bilbao location and at 2, 4, 6, and 8 weeks in the Sta.Barbara location. Stalks were topped at the internodes where leaf no. 7 was attached (the spindle leaf which is more than half unfurled is considered as leaf no. 1). Length of stalk, number of internodes and unfurled green leaves were also recorded.

The stalk samples were partitioned into internodes 7-9, 10-12, 13-15, and 16 or older counting from the top with the seventh internode corresponding to leaf no. 7. (Clements and Ghotb[3] have described leaf 7, 8, 9, etc as attached to internodes which essentially have reached their full length but which are still increasing in circumference.) The different sections were marked on each stalk and each stalk section in a bundle was chopped respectively and analyzed. The top section was fed first into the chopper followed by successive sections of the stalks. The weight of each section was determined as chopping progressed.

Samples after chopping were frozen and afterwards analyzed by the "pol-ratio" method (Payne and Mahon[10], de Saint Antoine[11]) for brix, pol (sucrose), and fiber. Reducing sugars were analyzed also for samples before spraying and at harvest by the Lane-Eynon method. From the primary data, sucrose % dry matter (S%DM), fiber % DM, DM % cane, moisture, and juice purity were computed. After the final samples before harvest were taken, the remaining cane from the center three rows were counted for number of millable stalks and stalks with lalas, cut at ground level, topped, and weighed. The number of germinating stools and tillers, and height of the subsequent ratoon crop in Bilbao were taken at 1 and 2 months after ratooning.

Rainfall, maximum, minimum, and mean temperatures were recorded weekly from 4 weeks before application up to harvest 6-8 weeks after spraying and are presented in Table 1.

RESULTS AND DISCUSSION

Morphological Changes

Visual effects

The visible effects on the cane plant after Mon 2139 treatment varied in some aspects in the two locations tested. However, a consistent and most marked effect was the inhibition of top growth which caused shortening of terminal internodes, followed by sideshooting.

In Bilbao where cane was more mature at time of spraying, reddening of the leaf sheaths and leaf blades starting from the midrib outward was observed 34 weeks after spraying. Hardening and discoloration of apical region followed by rotting occurred. Rotting started from the spindle cluster and spread downward to the region of the growing point which caused the top to break off in the case of the higher rates of Mon 2139. Splitting similar to the formation of growth cracks in the top internodes was apparent and hastened the deterioration of the internodes affected.

The less mature canes in Sta. Barbara showed blade and sheath symptoms

TABLE 1. Rainfall and temperature readings from 4 weeks before application to 6-8 weeks after application in the two glyphosate experimental sites.

Weeks before and after application	Bilbao[a]				Sta Barbara[b]			
	Rainfall (inches)	Temperature °C			Rainfall (inches)	Temperature °C		
		Max.	Min.	Mean		Max.	Min.	Mean
−4	1.22	32.2	23.4	27.8	0.51	31.4	22.6	27.0
−3	3.21	32.0	23.0	27.5	1.41	29.3	20.9	25.1
−2	0.84	31.3	23.0	27.2	6.50	29.5	22.3	25.9
−1	2.07	31.8	23.2	27.5	3.71	29.1	23.1	26.1
1	2.00 (0.11)	29.6	20.6	25.1	1.46(0.56)	28.8	22.3	25.6
2	3.70	29.0	22.1	25.6	1.30	29.5	22.4	26.0
3	5.76	29.8	23.0	26.4	1.21	29.3	22.8	26.1
4	3.24	29.2	22.3	25.8	0.00	29.4	21.5	25.5
5	1.52	28.6	22.5	25.6	0.00	29.0	20.9	25.0
6	1.30	29.6	22.7	26.2	0.88	30.2	22.7	26.5
7					0.00	29.5	22.4	26.0
8					0.00	30.5	22.9	26.7

( ) Rainfall on day of application
a Sprayed Nov. 21 & 22, 1978
b Sprayed Dec. 14 & 15, 1978

similar to those in Bilbao but a week later (about 4-5 weeks after spraying). Hardening and discoloration from brown to purple of apical region were also apparent but there was no sign of rotting and splitting until harvest. Formation of several sideshoots from a single node was also evident particularly in cane sprayed with Mon 2139 at 0.6 kg ai/ha.

Polaris treatment produced leaf speckling where the sprayed droplets hit the leaves, drying of leaves, sideshooting of eyes and shortening of upper internodes.

Rate of elongation and sideshooting

During the 6-8 weeks following treatment, the control plants formed an average of 4-5 new internodes while only 2 to 3 internodes developed with the ripener treatment. Stalk height of all plants treated with ripener was less than the control (Table 2). The only exception was the 0.3 kg ai/ha Mon 2139 treatment in Sta Barbara which gave almost the same number of internodes and stalk length as the control.

Plants treated with chemicals also showed formation of lalas (Table 2). The highest concentration of Mon 2139 in Bilbao tended to kill the lateral shoots. Fortunately, flowering which would have confounded the interpretation of results was not observed in any plot.

In the case of the treatments which inhibited internode development, the internodes counted down from internode 7 at harvest cannot be compared directly with those of the control. Internodes 7-9, 10-12 and 13+ of these treatments

TABLE 2. Internodes per stalk, stalk length, and percentage of stalks with lalas after treatment of 8-mo old Phil. 56-226 with Mon 2139 and Polaris.

Location	Treatment (kg ai/ha)	Internodes per stalk					Stalk length (cm)					% Stalk with lalas	
		0	2	4	6	8 weeks	0	2	4	6	8 after spraying	6	8
Bilbao	Control	18.6	21.2	22.2	23.8	–	192	209	213	224	–	0	–
	Mon 0.30	19.5	20.5	21.3	21.4**	–	195	206	213	212	–	16**	–
	Mon 0.60	18.8	20.8	21.7	21.2**	–	191	209	209	216	–	9**	–
	Mon 0.90	19.5	21.1	21.5	21.8**	–	191	211	212	215	–	2	–
	Polaris 5.1	19.4	21.2	21.6	21.6**	–	194	208	210	216	–	26**	–
	LSD(P0.05)	NS	NS	NS	1.3		NS	NS	NS	NS		6	
	(0.01)	NS	NS	NS	1.8		NS	NS	NS	NS		8	
	CV (%)	4.4	3.5	4.4	4.5		3.8	3.5	3.1	3.8		42	
Sta Barbara	Control	21.2	21.6	22.2	25.5	25.6	224	234	246	264	262	–	0
	Mon 0.30	20.8	21.6	22.6	24.2	25.1	224	231	247	265	262	–	10**
	Mon 0.60	20.6	21.8	22.5	22.9**	23.7*	226	233	248	255	274	–	12**
	Mon 0.90	20.9	22.1	21.8	22.8**	23.0**	225	237	249	245	246*	–	8*
	Polaris 5.1	21.5	22.1	22.1	23.2**	23.7*	227	235	242	248	250	–	16**
	LSD(P0.05)	NS	NS	NS	1.6	1.5	NS	NS	NS	NS	13		7
	(0.01)	NS	NS	NS	2.2	2.0	NS	NS	NS	NS	NS		10
	CV (%)	2.7	3.4	3.6	4.5	4.5	2.3	2.8	5.7	6.0	3.8		61

* *Difference from control significant at 5% level*
** *Difference from control significant at 1% level*

have to be compared with internodes 10-12, 13-15, and 16+, respectively, of the control to enable comparisons between internodes of similar or closer chronological age (see Table 3).

TABLE 3. Increase in mean number of internodes from spraying to harvest after treatment with Mon 2139 and Polaris of 8-mo old Phil. 56-226

Bilbao				Sta Barbara			
Control		Mon (all) Polaris		Control Mon 0.30		Mon 0.60 Mon. 0.90 Polaris	
IC[a]	FC[b]	IC	FC	IC	FC	IC	FC
+5	7						
+4	8			+4	7		
+3	9			+3	8		
+2	10	+2	7	+2	9	+2	7
+1	11	+1	8	+1	10	+1	8
7	12	7	9	7	11	7	9
8	13	8	10	8	12	8	10
9	14	9	11	9	13	9	11
10	15	10	12	10	14	10	12
11	16	11	13	11	15	11	13
12		12	14	12	16	12	14
13		13	15	13		13	15
14		14	16	14		14	16
15		15		15		15	
16		16		16		16	

a Initial internode count at spraying

b Final internode count at harvest (6 weeks after treatment in Bilbao and 8 weeks after treatment in Sta. Barbara)

Tissue moisture

Stalk moisture was determined by difference from the total fresh weight minus fiber and total dissolved solids (Brix). Moisture content was reduced at harvest by 30% with Mon 2139 and by 2% with Polaris. A reduction in number of green leaves accompanied the reduction in moisture content (Fig. 1). The dehydration occured with hardening of internodes especially with Mon 2139.

Fiber

In general, fiber % cane did not seem to be affected by ripener (Table 4). Fiber % dry matter decreased with treatment corresponding to an increase in the sucrose % dry matter.

Fresh weight per stalk

A reduction in the weight per stalk with either glyphosate or Polaris did

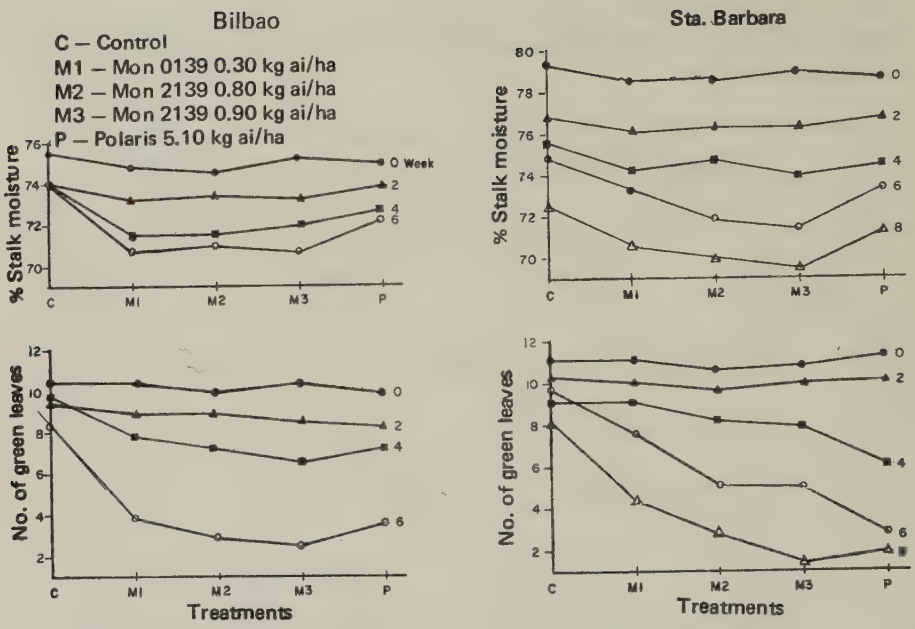

FIGURE 1. Moisture content of stalk and number of unfurled green leaves of Phil 56-226 as affected by Mon 2139 and Polaris at different weeks after application.

not occur in Bilbao (Table 5) although there was a decrease in stalk length and number of internodes at harvest. Based on actual number of millable stalks and weights of individual plots, there was a 3-10% reduction in weight per stalk with ripener treatment in Bilbao. However, this difference may partly be explained by the tendency of cutters to cut the treated canes lower because of the scanty appearance of the top especially with 0.6 and 0.9 kg ai/ha Mon 2139. The data on weight per stalk based on plot fresh weight yield in also quite variable (CV = 12%).

Weight per stalk decreased with ripener treatment 6 and 8 weeks after spraying in Sta Barbara when compared with the control. This was accompanied by a reduction in the length of stalk and number of internodes per stalk again compared with the control. The only exception was with 0.3 kg ai/ha Mon 2139 where there was very little or no reduction in number of internodes and length per stalk. The reduction in fresh weight with this treatment is probably largely due to normal variation. The data on actual plot weights in Sta Barbara were not presented because of missing observations. The tonnage was considerably heavier than that in Bilbao.

Ratoon regrowth

Since the effect of a ripener on the following ratoon crop is one of the important criteria for commercial use in the field, ratoon regrowth was examined.

One to two months after ratooning, leaf chlorosis was observed on all plants

TABLE 4. Fiber % cane and fiber % dry matter of different sections of stalk of 10-mo. old Phil 56-226 treated with Mon 2139 and Polaris 6-8 weeks before harvest

Location	Treatment (kg ai/ha)	Fiber % cane					Fiber % dry matter				
		Internode no.				Compo-site	Internode no.				Compo-site
		7-9	10-12	13-15	16+		7-9	10-12	13-15	16+	
Bilbao	Control	9.1	10.4	11.0	11.4	11.1	46.4	47.0	44.2	41.0	42.3
			7-9	10-12	13-15	16+		7-9	10-12	13-15	16+	
	Mon 0.30		9.6	10.3	10.8	11.4	11.0		37.5	37.8	36.9	37.8	37.7**
	Mon 0.60		10.0	10.4	10.9	11.3	11.1		40.1	38.4	37.8	38.0	38.2**
	Mon 0.90		10.2	10.6	11.0	11.7	11.4		42.5	38.9	37.8	38.4	38.7**
	Polaris 5.1		9.0	9.7	10.1	11.3	10.8		38.3	38.3	37.3	39.1	38.8**
	LSD (P0.05)						NS						1.5
	(0.01)						NS						2.1
	CV (%)						2.4						2.9
Sta Barbara	Control	10.0	10.3	10.7	11.1	10.9	39.3	39.7	39.2	39.3	39.3
	Mon 0.30	10.6	10.7	10.7	11.1	10.9	39.2	38.0	37.3	37.5	37.7*
			7-9	10-12	13-15	16+		7-9	10-12	13-15	16+	
	Mon 0.60		9.9	10.2	10.5	11.2	10.8		34.9	34.8	34.9	36.6	36.0**
	Mon 0.90		10.3	10.5	10.8	11.5	11.1		36.4	35.1	35.5	37.0	36.5**
	Polaris 5.1		9.7	10.0	10.3	11.1	10.7		35.9	35.8	36.5	37.6	37.1**
	LSD (P0.05)						NS						1.5
	(0.01)						NS						2.0
	CV (%)						3.6						3.0

* *Difference from control significant of 5% level*
** *Difference from control significant of 1% level*

TABLE 5. Fresh wt (kg) per stalk of Phil 56-226 at different times after treatment with Mon 2139 and Polaris

Location	Treatment (kg ai/ha)	Stalk weight (kg)[a] 0	2	4	6	8	Kg/stalk[bc] 6	8
		weeks after spraying						
Bilbao	Control	1.22	1.27	1.23	1.34	—	1.16	—
	Mon 0.30	1.24	1.25	1.35	1.34	—	1.11	—
	(101)[d]	(98)	(110)	(100)		(96)		
	Mon 0.60	1.16	1.33	1.30	1.35	—	1.08	—
	I (95)	(105)	(106)	(101)		(93)		
	Mon 0.90	1.21	1.35*	1.29	1.33	—	1.04	—
	(99)	(106)	(105)	(99)		(90)		
	Polaris 5.1	1.27	1.32	1.28	1.35	—	1.12	—
	(104)	(104)	(104)	(101)		(97)		
	LSD (P0.05)	NS	0.07	NS	NS		NS	
	(0.01)	NS	NS	NS	NS		NS	
	CV (%)	6.2	4.1	6.0	8.8		12.2	
Sta Barbara	Control	1.57	1.65	1.57	1.88	1.85	—	—
	Mon 0.30	1.48*	1.65	1.64	1.76	1.79	—	—
	(94)	(100)	(104)	(94)	(96)			
	Mon 0.60	1.60	1.71	1.67	1.68*	1.78	—	—
	(102)	(104)	(106)	(89)	(96)			
	Mon 0.90	1.56	1.75	1.63	1.68*	1.68*	—	—
	(99)	(106)	(104)	(90)	(91)			
	Polaris 5.1	1.53	1.73	1.60	1.68*	1.70*	—	—
	(97)	(105)	(101)	(90)	(92)			
	LSD (P0.05)	0.08	NS	NS	0.15	0.10	—	—
	(0.01)	NS	NS	NS	NS	NS		
	CV (%)	3.9	5.5	4.5	6.3	4.4		

a Based on samples used for height measurements and pol ratio analysis
b Based on number of millable stalks and actual weight of plot after cutting and topping in field by farm workers
c Data on actual weight of plot in Sta. Barbara incomplete
d Figures in ( ) refer to % control
e Difference from control significant at 1% level

sprayed with Mon 2139 and Polaris. Some control plots were also affected but to a lesser degree. (Ratoon chlorosis due to temporary iron deficiency is not uncommon in our commercial ratoon cane even if the soil is acidic). Table 6 shows a marked reduction in % stool germination, number of tillers per live stool and height of Phil56-226 in Bilbao when 0.6 and 0.9 kg ai/ha of Mon 2139 were applied. Mon 2139 at 0.3 kg ai/ha and Polaris stimulated tiller formation which is in agreement with previous work reported on Mon 2139 and Polaris (Gonzales and Tianco[7], Falgout[6]), Mon 8000 at 1 kg ai/ha in Mauritius (Anon[1]) appeared to seriously affect regrowth in one variety even at the highest rate (1 kg ai/ha) used.

TABLE 6. The effect of Mon 2139 and Polaris on ratoon regrowth of Phil 56-226 at Hda Bilbao 2 months after ratooning.

Treatments	% Germination[a]	Tillers/stool[b]	Height (cm)[c]
Control	63	2.8	13.5
Mon 0.30 kg ai/ha	69	3.1	13.5
Mon 0.60 kg ai/ha	55	2.4	10.8
Mon 0.90 kg ai/ha	29**	2.1*	8.2**
Polaris 5.1 kg/ha	76	3.1	14.2
LSD (0.05)	17	0.6	2.0
(0.01)	23	NS	2.7
CV (%)	22	18	12

a.) Based on number of stools
b.) Based on number of live stools
c.) Measured from ground to top visible develop
** Difference from control significant at 5% level*
** Difference from control significant at 1% level*

No data on ratoon regrowth in Sta Barbara were taken because the planter-cooperator plowed up his field. However, no adverse effect is expected with 0.3 kg ai/ha because the stalk weight and length of the plant crop was not significantly affected at this rate. Clowes[4] reported encouraging results in regrowth trials as chlorosis, when it occured, was only apparent during the first three months of growth.

Sugar Yield

Sucrose content

There was an average increase in pol % cane (P%C) at harvest of 16-25% in Bilbao and 17 to 28% in Sta Barbara with the application of chemical ripener (Table 7). The biggest % increase as expected occured in the uppermost 3 internodes with the % increase decreasing from the top section to the bottom section of the stalk. Comparisons should be made with sections of the same or closer chronological age.

Sucrose % dry matter (S% DM) was also computed to determine how much of the increase in P%C was due to actual accumulation of sucrose and not from an artificial dessication effect. The % increase in S%DM of 12 to 14% in Bilbao and 11-16% in Sta Barbara is less because of the lower moisture content at harvest of treated plants.

On the basis of either P%C or S%DM, the best treatment would be 0.3 kg ai/ha Mon 2139 in Bilbao and 0.6 to 0.9 kg ai/ha Mon 2139 in Sta Barbara. Polaris at 5.1 kg ai/ha, while giving a respectable 16-18% increase in P%C in both sites, did not effect as big an increase as 0.6 kg ai/ha Mon 2139.

Juice Purity

The ripening effect was associated with an increase in juice purity although

TABLE 7. Sucrose concentration in pol % cane and sucrose % dry matter of different sections of stalk of 10-mo old at harvest after treatment with Mon 2139 and Polaris

Location	Treatment (kg ai/ha)	Pol % cane					Sucrose % dry matter				
		Internode no.				Composite	Internode no.				Composite
		7-9	10-12	13-15	16+		7-9	10-12	13-15	16+	
Bilbao	Control	6.1	7.6	10.7	14.2	12.6	29.6	34.0	42.6	51.1	47.0
			7-9	10-12	13-15	16+		7-9	10-12	13-15	16+	
	Mon 0.30		11.9	13.4	15.4	16.7	15.8**		46.7	49.3	52.4	55.4	53.6**
	Mon 0.60		10.9	13.3	15.2	16.2	15.4**		43.5	49.3	52.8	54.6	53.1**
	Mon 0.90		9.5	13.4	15.2	16.6	15.5**		39.1	49.4	52.2	54.4	52.5**
	Polaris 5.1		10.8	12.6	14.2	15.4	14.6**		46.1	49.5	52.1	53.7	52.6**
	LSD (P0.05)						1.3						2.6
	(0.01)						1.8						3.6
	CV (%)						6.5						3.7
Sta Barbara	Control	8.7	10.3	12.7	14.2		13.1	34.4	39.7	46.4	50.6		47.5
	Mon 0.30	12.0	13.7	15.0	16.0		15.3**	44.1	48.8	52.0	54.4		52.5**
			7-9	10-12	13-15	16+		7-9	10-12	13-15	16+		
	Mon 0.60	14.7	15.7	16.7	17.0	16.5**		51.7	53.7	55.8	55.6	54.8**	
	Mon 0.90	13.0	15.7	17.0	17.6	16.8**		46.2	52.8	56.1	56.7	54.9**	
	Polaris 5.1	12.9	14.3	15.3	16.1	15.5**		47.9	51.1	54.0	54.7	53.6**	
	LSD (P0.05)					0.9						1.6	
	(0.01)					1.2						2.2	
	CV (%)					4.2						2.3	

* *Difference from control significant at 5% level*

** *Difference from control significant at 1% level*

TABLE 8. Juice purity of different sections of stalk of 10 mo old Phil 56-226 at harvest after treatment with Mon 2139 and Polaris

Location	Treatment (kg ai/ha)	Juice Purity Internode no. 7-9	10-12	13-15	16+	Composite
Bilbao	Control	54.8	64.0	76.4	86.6	81.0
			7-9	10-12	13-15	16+	
	Mon 0.30		74.8 (117)[a]	79.2 (104)	83.1 (102)[b]	89.1	86.0* (106)
	Mon 0.60		73.0 (114)	80.0 (105)	84.8 (101)[b]	88.1	85.9* (106)
	Mon 0.90		67.8 (106)	79.7 (104)	83.9 (101)[b]	88.4	85.4* (106)
	Polaris 5.1		74.8 (117)	80.3 (105)	83.1 (101)[b]	88.2	85.8* (106)
	LSD (P0.05)						3.3
	(0.01)						NS
	CV (%)						2.9
Sta Barbara	Control	56.9	65.9	76.4	81.8		77.2
	Mon 0.30	72.8 (128)	78.7 (119)	83.2 (109)	87.0 (106)		84.2** (109)
			7-9	10-12	13-15	16+	
	Mon 0.60		79.4 (120)	82.0 (107)	85.7 (106)[b]	87.4	85.8** (111)
	Mon 0.90		72.7 (110)	81.2 (106)	87.0 (110)[b]	90.1	86.5** (112)
	Polaris 5.1		74.7 (113)	79.5 (104)	84.7 (107)[b]	87.7	85.0** (110)
	LSD (P0.05)						2.5
	(0.01)						3.5
	CV (%)						2.3

[a] *Figures in ( ) refer to % of control*

[b] *Based on weighted average of 13-15 and 16 + sections*

* *Difference from control significant at 5% level*

* *Difference from control significant at 1% level*

the percentage increase over the control was lower than that of P%C or S%DM (Table 8). A comparison of juice purities of the different portions corresponding to the same chronological age shows that the ripener treatment at Bilbao increased juice purity considerably in the uppermost 6 internodes but increased juice purity only very slightly in portions below internode 12. There was an increase in P%C without an appreciable increase in juice purity in the bottom section with both glyphosate and Polaris. Clowes[4] referred to this situation as "loading".

Percent increase in juice purity over the control with the different treatments

TABLE 9. Weight (g) of sucrose per stalk of different sections of stalk of 10 mo old Phil 56-226 at harvest after treatment with Mon 2139 and Polaris

Location	Treatment (kg ai/ha)	Sucrose (g) per stalk: Internode no. 7-9	10-12	13-15	16+	Composite
Bilbao	Control	6.2	10.1	12.7	138.8	168
			7-9	10-12	13-15	16+	
	Mon 0.30		15.0 (149)[a]	16.6 (131)	28.0 (130)	152.3	212* (126)
	Mon 0.60		11.1 (110)	15.2 (120)	26.8 (130)	154.1	207* (123)
	Mon 0.90		10.4 (103)	16.1 (127)	26.8 (130)	153.0	206* (123)
	Polaris 5.1		12.0 (119)	14.9 (117)	24.0 (123)	146.7	198* (118)
	LSD (P0.05)						28
	(0.01)						NS
	CV (%)						10.7
Sta Barbara	Control	15.9	18.4	29.2	179.1		243
	Mon 0.30	23.3 (147)	23.0 (125)	30.8 (105)	196.5 (110)		273** (112)
			7-9	10-12	13-15	16+	
	Mon 0.60		30.1 (164)	36.0 (123)	34.5 (127)	192.8	293** (121)
	Mon 0.90		25.9 (141)	36.5 (125)	32.9 (123)	186.6	282** (116)
	Polaris 5.1		24.1 (121)	27.2 (93)	31.9 (118)	179.9	263* (108)
	LSD (P0.05)						18
	(0.01)						25
	CV (%)						4.9

[a] *Figures in ( ) refer to % of control*

* *Difference from control significant at 5% level*

** *Difference from control significant at 1% level*

occurred in all portions in Sta Barbara. The ripening effect of glyphosate and Polaris was associated with an increase in both P%C and juice purity. Clowes[4] referred to this process as "ripening" as distinguished from "loading." "Loading" can take place together with "ripening."

Sucrose per stalk

Our previous study has shown that glyphosate tended to reduce cane tonnage

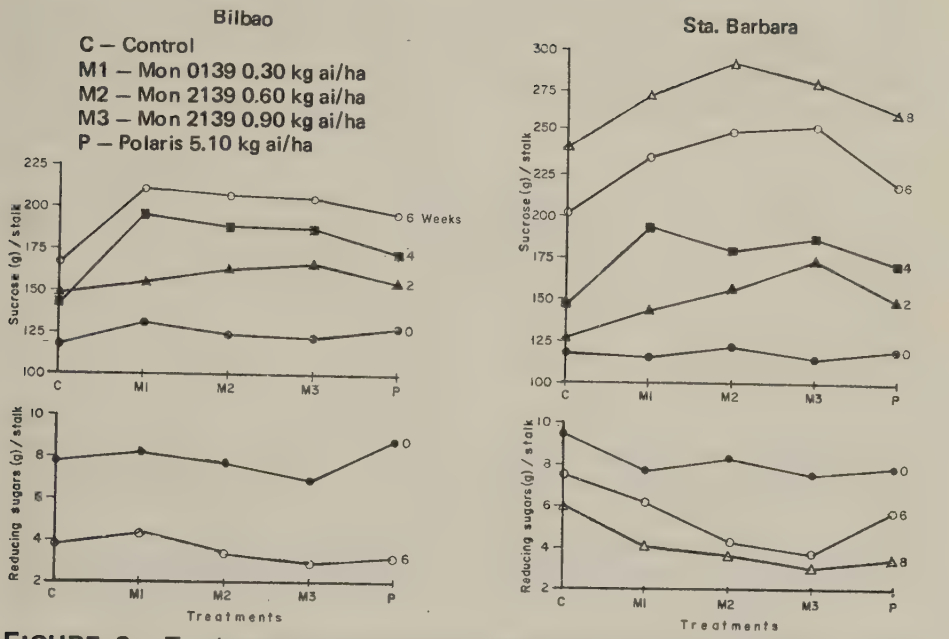

FIGURE 2. Total amount of sucrose and reducing sugars per stalk of Phil 56-226 as affected by Mon 2139 and Polaris at different weeks after application.

because of inhibition of apical growth. It is important, therefore, to determine if the improvement in juice quality can offset this weight reduction if it occurs. Grams sucrose was expressed on a cane stalk basis as the number of millable stalks per plot did not change during the experimental period from spraying to harvesting.

Table 9 shows grams sucrose of the different stalk portions with the different treatments and the control. The best treatment at Bilbao which was 0.3 kg ai/ha Mon 2139 caused an increase of 26% over the control. This increase corresponded to the increase in P%C because there was no reduction in the weight per stalk. This increase in sucrose by "loading" with an increase in total solids without a corresponding decrease in moisture in the bottom section would help explain why little or no reduction in weight per stalk was observed in Bilbao.

In Sta Barbara, the reduction in the weight which was accompanied by a reduction in length (except for 0.3 kg ai/ha Mon 2139) was responsible for the lowering of the % increase in total sucrose compared with the control. While 0.9 kg ai/ha Mon 2139 gave the highest P%C, 0.6 kg ai/ha gave the maximum increase in sucrose per stalk of 21% over the control because of its less detrimental effect on stalk weight.

Figure 2 shows the effect of ripener treatment on grams sucrose per stalk at different weeks after application. The optimum rate and time for Mon 2139 is 0.3 kg ai/ha 6 weeks before harvest in Bilbao and 0.6 kg ai/ha 8 weeks before

harvest in Sta. Barbara. Delaying the harvesting in Bilbao was not advisable because there were indications that stalks were starting to deteriorate at 6 weeks. Delaying harvesting was also not advisable in Sta Barbara because the stalk weight appeared to have peaked at 8 weeks.

Recent published results from Mauritius (Anon[1]) with the glyphosate group of compounds showed that Mon 8000 and XHH 48 applied at rates of 0.5 to 1 kg ai/ha significantly increased P%C and P%DM from 4 weeks after application. There were no significant differences between the rates mentioned. At the very low rate of 0.25 kg ai/ha, response appeared to be optimal at 6 weeks after application.

Reducing sugars

Reducing sugars concentration at harvest decreased as one went down from the top to the bottom portion of the stalk (data not shown). However, a comparison of grams reducing sugars per stalk with grams sucrose per stalk at harvest in Bilbao (Fig. 2) did not show a good inverse relationship. The best treatment of 0.3 kg ai/ha in fact had the highest % reducing sugars. This situation may be related to the "loading" phenomenon in the more mature portions of the stalk where the increase in sucrose is paralleled by the increase in total dissolved solids (Brix).

There is a better correlation between the total amount of reducing sugars and sucrose in Sta. Barbara which indicates the conversion of reducing sugars into sucrose as the cane matures. A serious drawback in using reducing sugars as a tool to determine the degree of maturity is the tediousness in performing the chemical procedure.

CONCLUSION

The estimation of the increase in sugar yield with ripener was complicated by the negative effect of the chemical on growth which is probable to occur for ripeners which inhibit top growth. Because of this variation in fresh weight yield, it was more accurate and convenient to express sucrose content on a cane stalk basis.

Partitioning of the stalk from the top downward was resorted to in order to monitor accurately the effect of the chemical on sucrose content in the upper internodes. While the response of relatively mature sugarcane in Bilbao (73% juice purity at spraying) was largely due to sucrose accumulation in the uppermost nine internodes (internodes 7-15), the bottom section accounted for 26-39%, of the sugar increase because it was responsible for 70% of the weight of the stalk.

In Sta. Barbara with immature cane (65% juice purity at spraying), the topmost 9 internodes (internodes 7-15) contributed about 30-60% of the sucrose increase with glyphosate. It was not possible to determine exactly the increase in the lower portion of the treated cane because partitioning was not done from the ground upward.

It seems that glyphosate and Polaris can increase P%C either by "ripening" or "loading" depending on the different conditions at spraying time such as juice purity, cane tonnage, and moisture content. The phenomenon of "loading" may largely account for the non-reduction in tonnage in many cases reported with Polaris usage. A rate of 0.3 kg ai/ha Mon 2139 may produce a "ripening" or "loading" response without affecting regrowth.

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EFECTOS DEL GLYFOSFATO MADURADOR EN EL CRECIMIENTO Y RENDIMIENTO DE AZUCAR DE LA CANA DULCE

A. P. Tianco y M. Y. Gonzales

RESUMEN

Dos pequeños cuadros de probaduras de campo se llevaron a cabo en Victorias, Negros, para evaluar el efecto del madurador de Glyfosfato como la formulacion Mon 2139 usando examen completo de analisis en divididos troncos desde arriba hasta abajo y expresando los resultados en base de por caña.

Hubo un promedio de aumento de 26% en gramos de sucrosa por tronco con 0.3 kg ai/ha. Mon 2139 con variedades de Phil 56 – 226 de 8 meses de caña dulce relativamente madura, fumigandolo 6 semanas antes de cosechar . . Aumento en el azucar no fue acompanado por una reduccion en el peso por caña. Fumigandolos con 0.6 kg ai/ha caña dulce inmadura de 8 meses de la misma variedad 8 semanas antes de cosechar resulto en un 21% de aumento en sucrosa por tronco. Este aumento podria haber sido mayor si la cana no se redujo por 4%.

Dividiendo los troncos mostro que mientras aumentos en pol % cana o sucrosa % materia seca eran mayores en la porcion de arriba (inter nudos 7 – 15), la seccion de abajo puede contar en gran parte (30 – 70%) de aumento de sucrosa debido al mayor peso de esta porcion y por el proceso de "cargar" ("loading") donde la sucrosa se acumula aun en las partes mas maduras del tronco. Este acompanamiento de sucrosa es paralelo o semejante a un aumento actual en el total de solidos disueltos con poca o casi nada de diferencia en la pureza del jugo.

No hubo efectos adversos en la germinacion, en troncos y en la estatura con 0.3 kg ai/ha Mon 2139 en un sitio y no se espera que la capacidad de retonar sea un problema en los otros cuadros porque habia poca reduccion o casi insignificante reduccion en el peso del tronco y del largor de la planta a esta medida. Los efectos de glyfosfato en el retono de vastagos y en el rendimiento de azucar requieren mas estudios.

EFFECTS OF EMBARK AND ETHREL ON SUGARCANE QUALITY, YIELD AND RATOON REGROWTH

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ABSTRACT

Four fields trials with Embark and Ethrel were carried out at four locations during 1975-77 to evaluate the effect of aerial spraying with both ripeners on sugarcane quality, yield and ratoon regrowth. Brix, growth rate and ratoon regrowth were measured in the field, and brix, Pol % cane, purity, available standard sugar % cane from stalk samples and mill-run crusher juice were analyzed. The results indicated that both Embark and Ethrel have substantial improvement in juice quality between 4 and 10 weeks after spraying.

The extent of increasing the sucrose content depends on varieties and age of cane. Ten-month old ratoon cane exhibited better ripening response to Embark than 15-month old autumn cane. Embark showed an increase of 7 to 28% and 15% in available sugar % cane over untreated cane 6-10 weeks after spraying for varieties F167 and F172, respectively. Embark at 2.5 l/ha could prevent the decline of sucrose content for variety F160 of spring cane at the end of the milling season. Ethrel demonstrated a good ripening effect on varieties F167, F172 and F177 of autumn cane at 8 to 10 weeks after treatment. The addition of urea in Ethrel spraying had no advantage.

Embark showed more suppression of growth rate in sugarcane than that of Ethrel. No substantial difference in cane yield was observed between Embark or Ethrel treated and control plots. Both Embark and Ethrel did not have apparent adverse effects on ratoon regrowth of succeeding crops. It appeared that Ethrel had a great potential in stimulating the regrowth of shoots in subsequent ratoon.

INTRODUCTION

The milling season in Taiwan is usually from early November to late April depending on the total yield. Due to the fact that sugar % cane is considerably lower during the first two months and the last one month of the milling season, some proper agronomic practices and adequate measures have been taken by Taiwan Sugar Corporation to enhance cane quality during this period. However, no obvious improvement has been observed during recent years due to various rea-

son (Yang and Ho[18]). Consequently any means of enhancing the cane quality and increasing sugar yield at these times would be of tremendous value to the sugar industry in Taiwan.

Chemical control of sugarcane ripening under adverse ripening conditions has been emphasized in many sugarcane growing countries in recent years. One of the chemical ripeners "Polaris" has been the most widely tested and has shown an excellent ripening response on different varieties and seasons in many cane areas. (Alves[2], Anon[3], Javier[7]. Julien[9], Legendre[10] Nickell[11]). Ethrel and Embark also have been proved to be highly successful ripeners in South Africa, Swaziland and Rhodesia when applied to immature sugarcane at the start of milling season. Alves *et al*[2] in Northeast Brazil reported that Polaris improved and prevented deterioration of juice quality of the ratoon crop when applied early in the decline phase of the maturity curve. However, the increase in sugar content is always at the expense of growth and the use of ripeners may sometimes cause adverse effects on the regrowth of subsequent ratoon crop.

Legendre[10] in Louisiana indicated that spraying with Polaris in August or early September when growth was very active, resulted in a 10 to 20% reduction in cane yield. Chapman[5] in Queensland conducted a series of trials with cane ripeners reported that Ethrel induced good C.C.S. gains in Bundaberg and Mackay for early-season ripening, but this gains was associated with a trend to reduce cane yield. While in the late-season trials, Polaris, Embark, Mon 0139 and Bualta II significantly arrested the C. C. S. decline. Julien[9] indicated that four out of ten industrial trials with Polaris showed symptoms of poor regrowth in succeeding ratoon cane. Jaramillo *et al*[8] in Colombia reported that 11/ha Ethrel plus 20 kg/ha urea produced the best C P - 57603 increase in sugarcane quality. However, conflicting results with Ethrel in addition of urea were obtained in Queensland (Chapman and Kingston[5]), South Africa (Rostron *et al*[13]) and Brazil (Anon[4]).

In Taiwan, approximately 20 chemicals have been tested in the sugarcane field over the past several years. Among them, Polaris has produced fairly consistent positive results both in small plot and aerial spraying trials (Yang and Ho[18]). Embark and Ethrel also have shown favorable ripening responses on some commercial varieties in small plot scale tests (Yang *et al*[17]). The object of this study is to evaluate the effect of aerial spraying with Embark and Ethrel on sugarcane quality, yield and ratoon regrowth under Taiwan's climatic and cultural conditions so as to ascertain the feasibility of commercial use of these ripeners in this area.

MATERIALS AND METHODS

Four aerial spraying field trials with Embark and Ethrel were carried out during 1975-77 at four locations. These mill areas are not blessed with favorable ripening conditions and always have to contend with adverse interactions of soil moisture and temperature during harvest time. Among them, three trials were conducted early in the milling season and one at the end of the season.

Embark (48% a.i., 4 S) is a trade name of MBR12325, given by 3 M company.

Chemically, this compound is a 2, 4-dimethyl-5 (trifluromethyl) sulfonyl amino phenyl acetamide.

Ethrel (48% a. i.) is a trade name given by Amchem Products Inc. The chemical name is 2-chloroethyl phosphonic acid.

Trial 1. Embark at the rate of 2.3 1/ha (1.1 kg a.e/ha) was sprayed on October 14 to 15, 1975 in Chihu and on October 22, 1975 in Pingtung. The total area sprayed in Chihu was 34.55 ha comprising 7 field blocks and one 8 ha comprising 3 field blocks in Pingtung. Each test block was divided into treated and check plots. Sugarcane in tests plots was harvested 6-8 weeks after spraying in both sites. Only small representative plots of sugarcane in Chihu remained in the field for further measurement to compare the maturity curve between treated and check plot.

Trial 2. Embark at the rate of 1.5 1/ha (0.72 kg a.i/ha) and 2.5 1/ha (1.2 kg a.i/ha) was sprayed at Liukuaitso and 1.5 l/ha alone at Tunghaifeng plantation in Pingtung on February 12, 1976, in an attempt to evaluate the effect of Embark on the quality of sugarcane in late milling season. The chemical was applied on three varieties of eleven-month old spring cane. The sugarcane in test plots was harvested approximately 10 weeks after treatment.

Trial 3. Ethrel at the rate of 2, 3 1/ha (0.96, 1.44 kg a.1/ha) and 2 1/ha Ethrel plus 20 kg/ha urea was applied on early-maturing variety F177 of nine-month old ratoon cane on October 14, 1976 in Pingtung. The sugarcane in test plots was harvested 9 weeks after treatment.

Trial 4. Ethrel at the rate of 2 l/ha and Embark at 2.3 l/ha were sprayed on varieties F177 of autumn cane and 60-587 of ratoon cane in Peikang and on varieties F167 and F172 of autumn cane in Huwei on October 15, 1977. The sugarcane in both test areas were harvested during December 17-31, 1977.

Each trial was laid out either in replicated strip at least 200 m long or whole blocks for aerial spraying and mill-run evaluation. Both ripeners were applied by helicopter, Bell 47 G-5, equipped with 64 D-2 nozzles, covering 24 rows 1.25 m apart, at the rate of 60 1 solution /ha with 0.1% by volume of surfactant. The height of application was approximately 3-6 m above the sugarcane canopy. Spraying was generally done between 6:30 a.m. to 11:00 a.m. The spraying speed of the helicopter was 64 km/hr and the wind velocity was in 1-4 m/sec. at the time of spraying.

Each treatment was generally divided into 5 to 6 plots for field brix determination and stalk sampling. Hand refractometer juice samples were taken from 5 stalks in each plot for brix measurement before spraying and at two weeks intervals thereafter. Each plot was sampled by taking 6 stalks at random prior to application and at regular weekly intervals thereafter. Cane samples were crushed by a test mill for the determination of brix, polarization, purity and available sugar % cane. For each treatment, mill-run crusher juice from every sixth loader was also sampled and analyzed for available sugar % cane during harvest.

In order to compare the effect of both ripeners on growth rate of different varieties, the length of the upper section from the top visible dewlap to the 8th internode (marked with red plastic tape as a base line) was measured before spraying from 20-60 stalks in each treatment. Few days before harvest, the marked stalks were cut at ground level, and the length, weight of upper and remaining section of the stalks were measured separately.

Final cane for each treatment was determined and recorded from wagon weights except for Trial 3.

The number of shoots (Trial 1 and 4), height and number of stalks and cane yield of the subsequent ratoon crop (Trial 1) were counted and measured at regular interval after harvest of previous treated crops.

RESULTS AND DISCUSSION

Visual symptoms

Embark generally produced no visible signs of drying off, yellowing or causing chlorosis of the leaves, its foliage always remained green up to harvest. However, some varieties, e.g. F167 and F170 in Chihu, occasionally showed a symptom of curliness in the spindle 4 weeks after spraying with Embark, resulting to more sideshoots induced at the upper section of the stalk.

The visible effect from application of Ethrel varied with the variety and the age of treated cane. The leaves generally shortened and turned into yellow-orange color at 4th week after spraying. These symptoms were more obvious on varieties F167 of autumn cane and 60-587 of ratoon cane. Many sideshoots were observed on the top nodes of the stalks, particularly for variety F172 of autumn cane 8 weeks following Ethrel treatment. No sideshoots were noticed on variety F177 of autumn cane.

Cane quality

The brix measured in the field from standing cane had a similar trend of maturity curve to that determined from crusher juice in laboratory. Both Embark and Ethrel produced a substantial improvement in juice quality between 4 and 10 weeks after spraying. The extend of increase in sugar % cane depended on varieties and the time of spraying. Embark showed an increase of 7%, 14% and 16% in available sugar % cane over those of untreated cane 6-8 weeks after treatment on varieties F167 and F170 of ratoon cane and F167 of autumn cane in Chihu and Pintung, respectively (Table 1).

Similar positive results were obtained in Huwei for varieties F167 and F172 of autumn cane, produced 28% and 15% increments of available sugar % cane analyzed from mill-run crusher juice 9-10 weeks after spraying (Table 4). It appeared that the positive ripening response persisted up to 10 weeks after Embark treatment for F167 and F170 of ratoon cane in Chihu (Fig. 1). These results con-

TABLE 1. Comparison of juice quality in different varieties 6-8 weeks after spraying with Embark (Trial 1).

Location	Variety	Brix		Pol		Purity		Available sugar % cane		Percent increase
		R	CK	T	CK	T	CK	T	CK	
Chihu	F167 (1)	17.33	17.69	14.64	15.07	84.23	85.04	10.31	10.65	
	F167 (2)	17.34	16.85	14.81	14.07	85.39	83.47	10.54	9.84	7 *
	F170 (1)	18.73	18.66	16.49	16.25	87.91	87.12	11.93	11.69	2
	F170 (2)	18.43	16.82	15.56	13.81	84.21	81.86	10.95	9.57	14**
	Mean	18.12	17.50	15.48	14.76	85.26	84.14	10.99	10.40	6
		±0.59	±0.64	±0.69	±0.99	±1.58	±2.19	±0.60	±1.15	
Pingtun	F156 (1)	16.08	16.04	13.94	13.46	86.66	83.85	9.94	9.46	5
	F160 (1)	17.14	18.20	14.33	15.84	83.32	86.94	10.05	11.34	
	F167 (1)	19.44	18.00	16.90	14.94	86.86	82.83	12.04	10.40	16*
	Mean	17.55	17.41	15.06	14.75	85.61	84.54	10.68	10.40	3
		±1.40	±0.98	±1.31	±0.98	±1.62	±1.75	±0.97	±0.77	

*Notes: (1) Autumn cane (2) Ratoon cane (3) ** L.S.D. (P 0.01)*
*(4) Data determined on stalk samples * 9p 0.05)*

TABLE 2. Comparison of mill-run crusher juice 10 weeks after spraying with Embark in the decline phase in Pingtung (Trial 2)

Plantation	Variety	Treatment	Brix	Pol	Purity	Available sugar % cane	Percent increase
		Embark 2.5 1/ha	19.66	16.66	84.74	11.13	11*
	F160	Embark 1.5 1/ha	17.34	15.00	86.51	10.13	1
		CK	17.48	14.91	85.30	9.99	
Liukuaitso							
		Embark 2.5 1/ha	17.75	15.13	85.55	10.16	5
	F167	Embark 1.5 1/ha	17.00	14.41	84.79	9.63	
		CK	17.07	14.61	84.94	9.71	
	F156	Embark 2.5 1/ha	19.36	16.26	83.99	10.81	6
		CK	18.82	15.26	80.55	9.84	
Tunghaifeng							
		Embark 2.5 1/ha	18.06	15.28	84.67	10.20	6
	F167	CK	17.00	14.41	84.79	9.63	
		Embark 2.5 1/ha	18.71	15.83	84.74	10.58	8
Mean		Embark 1.5 1/ha	17.17	14.71	85.65	9.88	1
		CK	17.59	14.77	83.90	9.79	

*Notes: (1) All varieties belong to spring cane (2) * L. S. D. (P 0.05)*

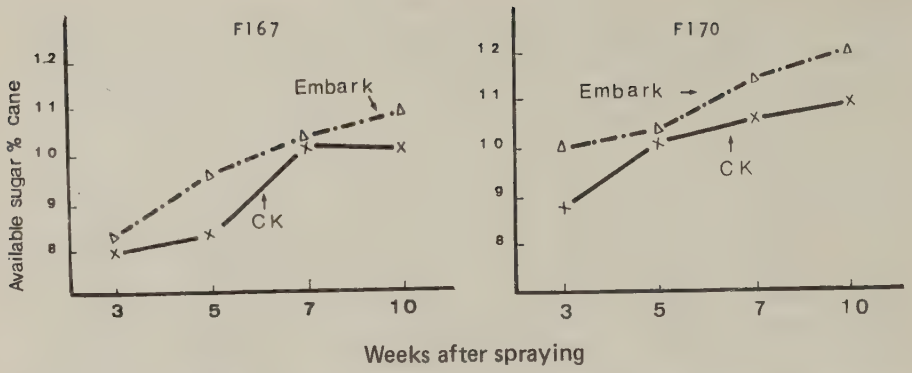

FIGURE 1. Changes in available sugar % cane after spraying of Embark on varieties F167 and F170 of ratoon cane (Trial 1).

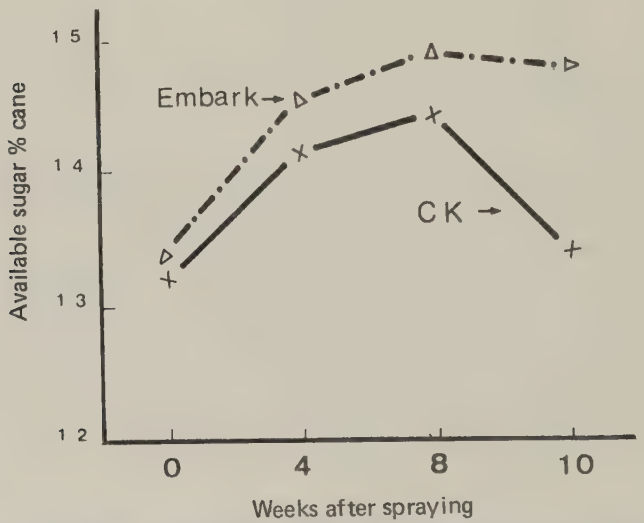

FIGURE 2. Changes in available sugar % cane after spraying of Embark on variety F160 of spraying cane in the late milling season (Trial 2)

firmed those of Takahashi[16] who found that maximum ripening with Embark occurred at the 8th week and again at 11 weeks in Hawaii.

In comparison of ripening effect of Embark between plant cane and ratoon cane, the latter showed better ripening response than the former (Table 1). Both F167 and F170 of ratoon cane exhibited significant positive response to Embark than that of autumn planted cane. Fig. 2 showed a favorable ripening response for F167 and 60-587 following Embark treatments.

In the late-season trial, Embark at 2.5 1/ha produced a significant effect to prevent a decline in cane quality of F160 of spring cane 10 weeks after spraying (Fig. 3). Both F156 and F167 treated with Embark at 2.5 1/ha also increased

TABLE 3. Comparison of mill-run crusher juice 9 weeks after spraying with Ethrel on variety F177 of ratoon cane (Trial 3)

Treatment	Brix	Pol	Purity	Available sugar % cane	Percent increase
Ethrel 2 1/ha	18.07	14.43	79.86	9.11	3
Ethrel 2 1/ha	17.91	15.04	84.02	9.77	10 **
Ethrel 2 1/ha iurea 20 kg/ha	17.34	13.96	80.49	8.85	
CK	17.65	14.05	79.57	8.85	

*Note: ** L. S. D. (0.01)*

TABLE 4. Comparison of mill-run crusher juice 9-10 weeks after spraying with Ethrel and Embark (Trial 4)

Variety	Treatment	Brix	Pol	Purity	Available sugar % cane	Percent increase
	Ethrel	14.63	11.24	76.86	6.73	12 *
F167	Embark	15.59	12.43	79.63	7.73	28 **
	CK	15.35	10.70	69.66	6.03	
	Ethrel	17.09	13.86	81.10	8.93	6
F172	Embark	17.21	14.68	85.28	9.71	15 **
	CK	15.77	13.01	82.43	8.46	

*Notes: * L. S. D. (P 0.05) ** L. S. D. (P 0.01)*

about 6% of available sugar % cane compared with untreated cane (Table 2), despite the weather pattern over the trial period was conducive to natural ripening (The rainfall was very scarce in comparison with the normal year[3]). However, no positive response on arresting sucrose decline was observed in the plots treated with Embark at 1.5 1/ha (Table 2).

Ethrel revealed a good ripening response for varieties F167 and F172 of autumn cane, it increased sugar % cane approximately 6-12% determined from mill-run crusher juice over the untreated check at 9-10 weeks after spraying (Table 4). Fig. 4 demonstrate the substantial increase in available sugar % cane at 8th week following Ethrel treatment on F172 and F177 of autumn cane.

In trial 3, application of Ethrel at the rate of 3 1/ha showed a better positive response than the rate of 2 1/ha. This result exhibited similar trend obtained in South Africa. Rostron[14] indicated that a rate of 3.1 1/ha (1.5 kg a.i/ha) Ethrel gave a slightly better average response of 1.0 ters/ha compared with a response of 0.8 ters/ha at rate of 2.2 1/ha (1.0 kg a.i/ha) in semi-commercial field trials. However, in other trials there had been only little difference between rates of application of 1.1 and 2.2 1/ha. In Swaziland, the rate of 3 1/ha of Ethrel produced little more sugar than that of 2 1/ha (Rostron *et al*[13]). The conflicting results obtained

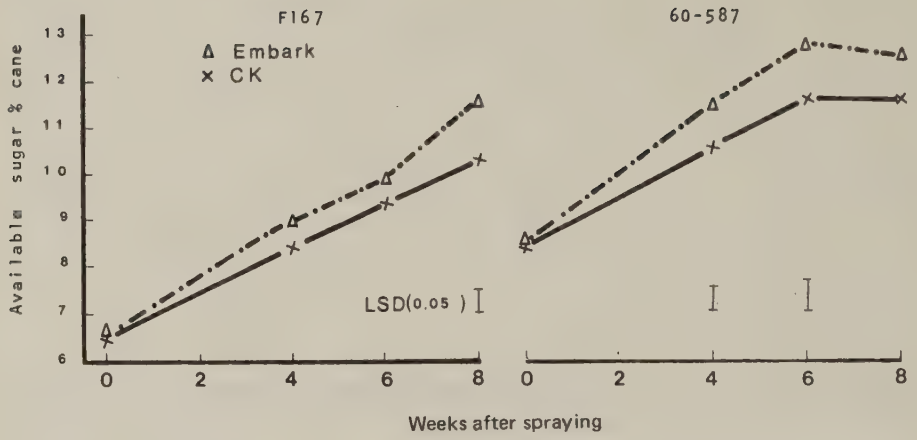

FIGURE 3. Changes in available sugar % cane after spraying of Embark on Varieties F167 and 60-587 (Trial 4)

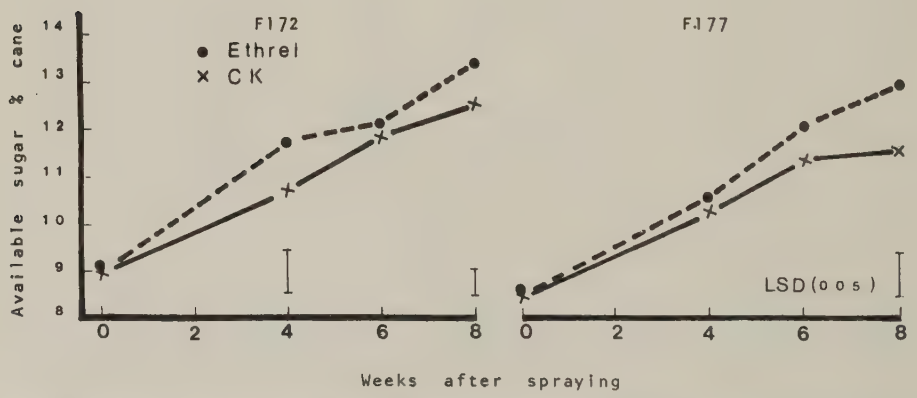

FIGURE 4. Changes in available sugar 5 cane after spraying of Ethrel on varieties F172 and F177 (Trial 4)

in these trials in various areas might be attributed to the differences in the conditions of the crop such as age and natural ripening at the time of application.

Ethrel in combination with 20 kg urea did not show evident ripening effect on variety F177 of ratoon cane, confirming the results obtained in Queensland (Chapman and Kingston[5]), Swaziland (Rostron *et al*[13]), and Brazil (Anon[4]).

Growth rate and cane yield

Application of chemical ripeners usually accompanies a reduction in growth rate, particularly for Polaris treatment (Javier *et al*[7], Legendre and Martin[10], Rostron[12], Yang *et al*[17]). However, some difference in growth rate was observed

TABLE 5. Effect of Embark on growth rate of sugarcane (Trial 1)

Chihu		Pingtung	
Variety	Growth reduction %	Variety	Growth reduction %
F167 (1)	0.17	F156 (1)	0.64
F167 (2)	0.88	F160 (1)	1.80
F170 (1)	0.51	F167 (1)	0.21
F170 (2)	1.11		

Notes: *(1) Autumn cane*
(2) Ratoon cane
(3) Growth reduction is compared with check plot
(4) Each figure represents a mean of 20 to 60 stalks

TABLE 6. Harvest data for cane yield determined from wagon weights treated with Embark (Trial 1)

Location	Harvest areas (ha)		Mean cane yield (m.t./ha)		No. of field block	
	T	CK	T	CK	Increased	Decreased
Chihu	34.55	41.30	78.9	86.0	3	4
Pingtung	8.00	16.61	98.2	87.6	2	1

TABLE 7. Effect of Embark on growth rate and yield of sugarcane in the late milling season (Trial 2)

Treatment	Growth rate in %			Cane yield (m.t./ha)		
	F160	F167	F156	F160	F167	F156
Embark 2.5 l/ha	4.20	4.38	3.45	70.19	73.58	78.03
Embark 1.5 /ha	2.45	4.10		90.58	85.37	
CK	4.05	4.05	4.25	81.34	82.39	78.58

Note: All varieties belong to spring cane

between Embark and Ethrel treatments.

Since Embark can also be used for grass growth retardation, it showed more suppression of growth rate in sugarcane than that of Ethrel. Embark showed 0.17% to 1.80%, 0.80% to 1.60% and 0.39% to 1.59% decrease in mean growth rate (weight) compared with untreated cane in Trial 1, 2 and 4 respectively (Tables 5, 7 and 9). In contrast to these results, Ethrel demonstrated consistent increase in mean growth (weight) by 1.03% to 3.34% compared with untreated cane in Trial

TABLE 8. Effect of Ethrel on growth rate of sugarcane (Trial 3)

Treatment	Mean wt. per stalk (g)	Growth rate in wt. (g)	Growth rate in %	Compared to CK in %
Ethrel 2 /ha	1388	88	6.3	- 0.1
Ethrel 3 /ha	1379	111	8.0	+ 1.6
Ethrel 2 /ha + urea 20 kg/ha	1365	65	4.8	- 1.6
CK	1322	84	6.4	

Note: Each figure represents a mean of 25 stalks.

4 (Table 9). It seems that Ethrel could stimulate cane growth after treatment. There was some evidence that growth stimulation induced by Ethrel might differ between varieties. In South Africa, stimulation of growth from Ethrel treatment did not occur on variety NCO376 (Clowes[6]) but might occur in varieties N55/805 (Rostron[12]) and N52/219 (Clowes[6]). Alexander *et al*[1] indicated that sugarcane's rapid growth phase could be extended in conjunction with chemical treatments to accelerate natural ripening.

No marked difference in growth rate was observed for application rate either between 1.5 l/ha and 2.5 l/ha for Embark or 2 l/ha and 3 l/ha for Ethrel (Table 7 and 8).

In comparison of cane yield between treated and check plots determined from wagon weights, the plots treated with Embark showed a decrease of 8% and increase of 12% Chihu and Pingtung, respectively (Trial 1). In Trial 2, the cane treated with Embark at 2.5 l/ha exhibited a decrease of 1%-14% and an increase of 4%-11% for Embark at 1.5 l/ha (Table 7). In Trial 4, it showed a decrease of 4-6% for three varieties and an increase of 11% for F177 following Embark treatment. In Ethrel treated plots, a decrease of 6% for F172 and an increase of 1–4% for three varieties were observed (Table 9).

It is interesting to note that greater cane yield depressions were always accompanied by improvement of quality for Embark treatment (Trials 1, 2, and 4) but did not show the similar trend for Ethrel treatment (Trial 4).

Ratoon regrowth

The visible effect on shoot regrowth following ripener treatment varied with ripening agent and variety. Some chlorosis of leaves was found in Polaris treated plots for variety F160 two months after harvest (Yang and Ho[18]). Recently, a similar symptom was also observed on variety F172 treated with Polaris (Yang and Ho[18]). However, no such special symptom was detected in the new shoots developed from the ratoon cane treated with Embark and Ethrel.

The number of tillers was consistently increased at early sprouting stage in the plots previously treated with Embark and Ethrel except the variety F177

TABLE 9. Effects of Ethrel and Embark on growth and yield of sugarcane (Trial 4)

Variety	Treatment	Stalk height (cm/stalk)		Stalk weight (g/stalk)		Growth rate wt. per stalk (%)		Sideshoot per 20 stalks (3)(4)	Cane yield (m.t./ha)
		Growth in length after treat	Compared to CK	Mean wt. per stalk	Growth in wt. after treat	Growth rate	Compared to CK		
F167(1)	Ethrel	21.60	+ 3.65	2170	76.6	3.53	+1.03	37/ 9	148.42
	Embark	6.35	−11.60	1697	16.1	0.91	−1.59	57/17	135.94
	CK	17.95		1823	46.0	2.50		10/ 2	142.86
F172(1)	Ethrel	16.35	+ 7.50	1697	72.2	4.25	+3.34	89/16	106.80
	Embark	7.60	− 1.25	1625	16.9	1.54	+0.13	38/11	107.02
	CK	8.85		1693	15.4			1/ 1	113.73
F177(1)	Ethrel	15.50	− 3.00	1595	52.2	3.27	+2.30	3/ 1	112.69
	Embark	10.40	− 8.10	1665	54.6	3.28	+1.31	5/ 1	124.96
	CK	18.50		1758	34.6	1.97		0	112.17
60-587(2)	Ethrel	17.20	+ 7.30	1124	60.6	5.39	+2.37	33/ 8	90.15
	Embark	10.70	+ 0.80	1037	27.3	2.63	−0.39	5/ 1	83.55
	CK	9.90		1050	31.7	3.02		0	87.35

Notes: (1) Autumn cane (2) Ratoon cane (3) No. of sideshoots
(4) No. of stalks occurring sideshoots
(5) Each figure in growth measurement represents a mean of 20 stalks.

TABLE 10. Effect of Embark on growth and cane yield of subsequent ratoon cane (Trial 1)

Location	Variety	Tillers (thousands/ha)		Stalk height (m)		(No. of stalks (thousands/ha)		Cane yield (m.t./ha)	
		T	CK	T	CK	T	CK	T	CK
Chihu	F167	24.8	18.8	2.27	2.43	64.3	65.0	71.16	74.69
	F170	53.6	45.4	2.32	2.08	95.2	96.3	89.67	75.12
	Mean	39.2	32.1	2.30	2.25	79.8	80.7	81.49	74.93
Pingtung	F156	45.2	41.2	2.52	2.55	66.4	64.8	80.52	80.70
	F160	79.5	72.2	2.43	2.45	68.8	67.5	70.49	71.60
	F167	52.6	44.9	2.43	2.47	66.1	65.4	67.84	63.48
	Mean	59.1	52.8	2.46	2.49	67.1	65.9	72.61	71.45

Note: The number of tillers was counted during February to March, 1976, stalk height and no. of stalks measured in August 1976. Cane yield was weighed at harvest from January through May 1977.

treated with Embark (Tables 10 and 11). In Trial 4, the plots formerly applied with Ethrel showed a great increase in tiller population than that of check plot for F177 and 60-587 (Table 11).

Based on the growth measurements taken in Chihu and Pingtung in Trial 1, there was no significant difference in stalk length and number of stalks between the plots applied with and without Embark, confirming the result of Clowes[6].

The harvest data obtained from seven test blocks treated with Embark in Trial 1, exhibited no marked difference in ratoon yield between treated and check plots except for variety F170 in Chihu. The treated plot had a large increase in ratoon cane yield over check mainly due to field variation (Table 10).

Results obtained so far indicate that neither Embark nor Ethrel has an apparent adverse effect on ratoon regrowth of subsequent crop under Taiwan's climatic and cultural conditions.

TABLE 11. Effects of Ethrel and Embark on tillers of subsequent ratoon cane (Trial 4)

Treatment	F 167	F 172	F 177	60-587
Ethrel	58.72	93.28	217.01	210.30
Embark	58.56	95.36	174.03	174.03
CK	57.84	91.68	190.38	158.61

Note: *The number of tillers was counted in mid-April 1978*

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EFFECTOS DE EMBARK Y ETHREL SOBRE LA CALIDAD DE LA CAÑA DE AZUCAR, RENDIMIENTO Y RETOÑAMIENTO.

F. C. Yang y F. W. Ho

RESUMEN

Se llevaron a cabo cuatro ensayos con Embark y Ethrel en cuatro lugares durante 1975-77 para evaluar el efecto de la aplicación aerea de ambos maduradoras sobre la calidad de la caña de azucar, rendimiento y retonamiento. Brix, crecimiento y retonamiento se midieron en el campo, y brix, Pol %, cane, pureza, azucar estandar obtenible % caña fueron analizadas del jugo del molino. Los resultados indicaron que tanto Embark como Ethrel mejoraron substancialmente la calidad del jugo entre 4 y 10 semanas despues de aspejarse. La magnitud del aumento del contenido de azucar dependiendo de las variedades y la edad de la caña. Retoños de 10 meses de edad respondieron mejor en maduración al aplicarsele Embark que gran cultura (caña de Otoño) de 15 meses de edad. Embark mostro aumentos de 7 e 28% y 15% de azucar disponible % caña en comparacion con caña no tratada de 6 a 10 semanas despues de asperjar para las variedades F 167 y F 172, respectivamente. Embark a 2.5 l ha pudo prevenir la merma en el contenido de azucar para la variedad F 160 de primavera al final de la zafra. Ethrel demonstro un buen afecto de maduración sobre las variedades F 167, F 172 y F 177 de gran cultura de 8 – 10 semanas despues de tratadas. La adicion de urea al Ethrel no fue ventajosa.

Embark mostró mas supresion al crecimiento de la caña de azucar que Ethrel. No se observó ninguna diferencia significativa entre los rendimientos de caña tratada con Embark o Ethrel y las parcelas testigo. Ni Embark ni Ethrel aparentemente tuvieron efectos adversos sobre el retonamiento. Parecio que Ethrel pudo estimular el ahijamiento en subsiquientes retoños.

THE CONCENTRATION OF JUICE OF DIFFERENT JOINTS ALONG SUGAR CANE STALKS

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ABSTRACT

The observation of two cases in which the normal variation of the concentration of the juice along sugar cane stalks has been drastically upset was reported.

A case refers to the distribution of juice concentration observed along stalks produced by second ratoon from a seedling taken from the field. Of the seven stalks of the stool, one showed a Brix % on juice which was low at joints near the base (about 14% Brix), and increased to a maximum during the harvest season towards the top of the cane stalk (22.9% Brix at the last joints, at the last testing date on 11 September 1978). Purity values determined at this date were higher than 90% even in the low Brix joints. Another five stalks showed similar abnormalities, although not as striking. Only one stalk in the stool showed what can be considered a normal distribution of juice concentration.

The other case refers to the distribution of juice concentration observed along stalks that suffered some frost damage. In these stalks a low Brix % value (about 13% in some cases) was found in the juice of the lower joints. Brix % increased toward the top of the stalk, up to values higher than 21% in some cases. This was a prevalent phenomenon affecting an important proportion of the commercial field still standing at the end of the 1978 harvest at Tacuman, Argentina.

INTRODUCTION

It is generally accepted that the concentration of the juice of the above-ground joints of sugar cane stalks is higher near the base and decreases toward the top (Alexander[1] van Dillewin[4]). The purpose of this note is to report the observation of two cases which do not follow the general trend.

The first case refers to the distribution of concentration observed along

stalks obtained as second ratoon from a seedling taken from the field at Estacion Experimental Agricola de Tucuman. During the harvest season the Brix % along the stalks was followed, and six of the seven stalks of the stool showed abnormalities, which were rather striking in one of them (stalk 5).

The second case refers to commercial plantations which had suffered some damage by frost (leaves and top arrow were destroyed). In this case an important proportion of the fields showed stalks with a notable depressed Brix % in the lower part, with higher values toward the top.

MATERIALS AND METHODS

As mentioned, in the first case the material consisted of a stool of seven stalks produced by second ratoon of a seedling taken from the field at the Estacion Experimental Agricola de Tacuman, and of another 50 stalks nearby. Brix % was measured at different joints along the stalks at three dates during the harvest season with a field refractometer. At the date of the last observation several joints (not punched in previous Brix observation dates) were individually pressed and Brix % (by laboratory refractometer) and Pol % (by weighing and diluting to 100 ml, and clarifying with dry basic lead acetate) were determined in some of the stalks.

For the second case, samples were taken from commercial fields which were damaged by frost in the 1978 season in the province of Tucuman, Argentina. The analytical methods were the same as mentioned for the first case.

RESULTS AND DISCUSSION

The First Case

Fig. 1 shows the variation of Brix % taken with field refractometer at the indicated three dates during the harvest season on one of the stalks (no. 5) of the stool mentioned above. The values labeled 4/6/78 show that at that date the Brix % of the juice had a comparatively low value at the lower joints increased to a maximum somewhat above the middle of the stalk, and decreased again toward the top of the stalk. The other curves show that this concentration profile changed during the harvest season with the concentration peak towards the top of the stalk, on 11/9/78 (Fig. 2).

Fig. 2 also shows the values of Brix % and Pol % of the juice of joints of the same stalk, and the corresponding Purity values. The Brix % values confirm those obtained by field refractometer. The Purity values are worth noting due to their high level, even in the low Brix juices. In fact, this situation constitutes an exception to normal Brix-Purity relations in normal cane stalk sections, in Fig. 3 the results of Fig. 2 are plotted in the Brix-Purity plane. The region of the plane labeled "Normal Zone" represents the region which contained the points obtained

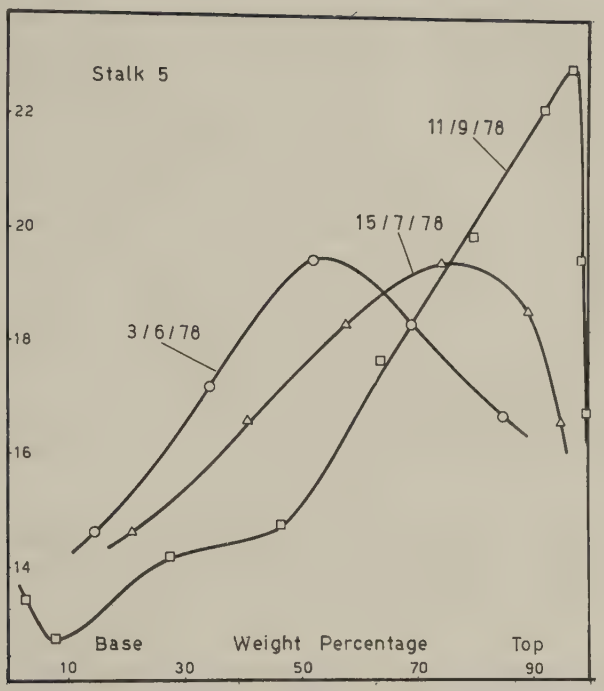

FIGURE 1: Evolution of Brix % along stalk no. 5 during the harvest season.

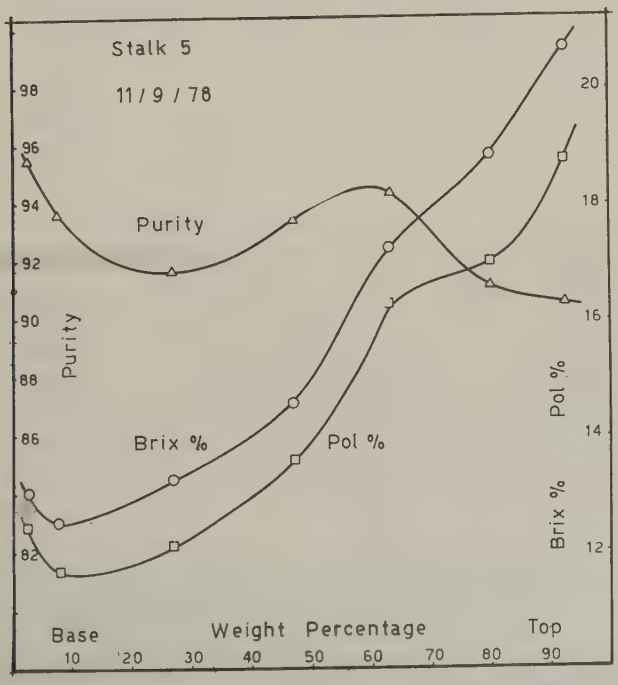

FIGURE 2: Brix %, Pol %, and Purity along stalk no. 5 at 11/Sept./78.

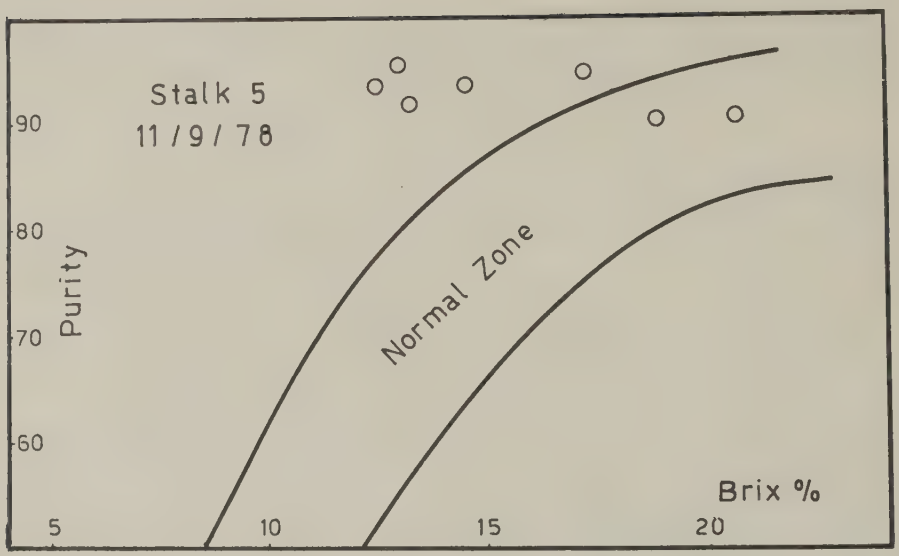

FIGURE 3. Brix-Purity values obtained for stalk no. 5

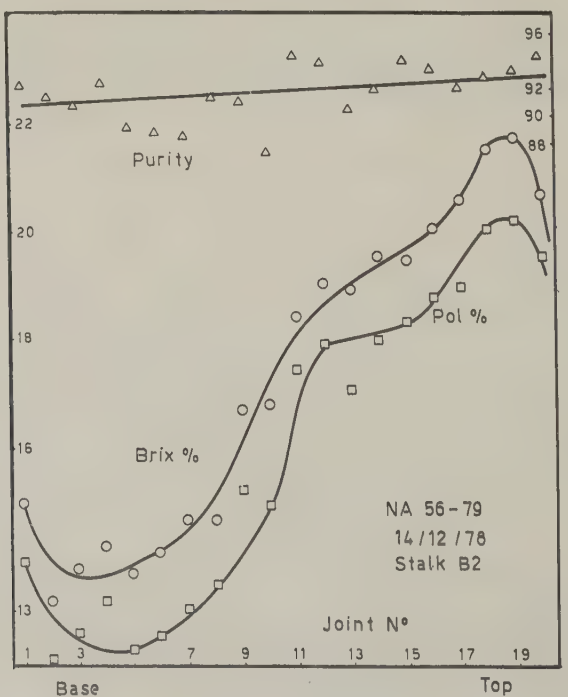

FIGURE 4. Variation of Brix %, Pol %, and Purity along a stalk of an Na 56-79 field affected by frost.

with fresh cane stalk sections analyzed in the laboratory in the years 1974-1978. It can be seen that several of the Brix-Purity points corresponding to the considered stalk, lay far outside of the normal zone.

At the first observation date (first days of June) three of the seven stalks of the stool already showed anomalous distribution of concentration similar to that of stalk no. 5 just described, but at the last observation date (middle of September) six of the stalks showed some degree of abnormality, characterized by a concentration peak near the top of the stalks. Only one of the seven stalks of the stool showed normal distribution of concentration at the three observation dates (detailed information will be published in a separate report by Hoffmann[2])

The stalks under consideration had no external indication of abnormality, did not show symptoms of severe disease, were not affected by frost and did not show lateral shoots. Only two joints in the seven stalks were damaged by the borer.

Another 50 stalks, originating from other seedlings planted in the surroundings, were checked for their concentration tendency, and all were found normal.

The Second Case

The second situation of interest arose when stalks of NA 56-79, the more extensively planted variety in Tucuman, were analyzed joint by joint in December, 1978, in fields that had been affected by frost. The results obtained in one of these stalks are shown in Fig. 4. The low values of concentration toward the lower part of the stalk are striking. Purity values were rather high in the juice of all joints (usually above 90%). These values, taken to a Brix-Purity graph show deviations from the normal zone in a similar way as in the previous case.

After the discovery of this abnormality (Dec. 14, 1978), stalks of other varieties and from different places in the province were analyzed. Another example is given in Fig. 5 for the variety Tuc 68-19. It was found that probably more than 30% of the fields left standing were affected by the phenomenon. All the fields in which the abnormality occurred had leaves and top arrows damaged by frost, and the stalks had grown lateral shoots from the upper buds. However these were not of common occurrence because in some fields in which they occurred the stalks showed the normal distribution of concentration approximately uniform all along the stalk.

During the harvest season the concentration began to decrease, unaccountedly. One of the factories yet milling at the end of the season experienced during November a drastic drop in the Brix % of the first juice extracted.

The frequency of this phenomenom occurring in cane damaged by frost is unknown, but from the data of factory reports it has been observed that seasons

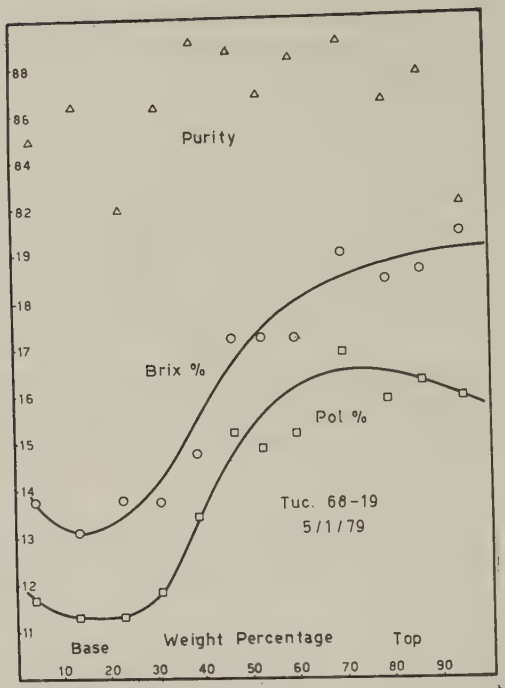

FIGURE 5. Variation of Brix %, Pol %, and Purity along a stalk of a Tuc 68-19 field affected by frost.

affected by frost are characterized by lower values of Brix % in the first juice that is extracted. It is reasonable to suspect that part of this Brix % decrease is due to this phenomenom.

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LA CONCENTRACION DEL JUGO EN DIFERENTES NUDOS A LO LARGO DE LOS TALLOS DE CANA DE AZUCAR

C. Hoffmann

RESUMEN

El proposito de esta communicacion es informar la observacion de dos casos en los cuales la variacion normal de la concentracion de jugo a lo largo de los tallos de cana han sufrido un vuelo drastico. Uno de estos casos se refiere a la concentracion del jugo observado a lo largo de los tallos producidos por caña soca de 2 años en un seedling llevado a campo. De los siete tallos de la planta madre uno mostro un Brix % en jugo que ha sido bajo en las juntas (nudos) cerca de la base. (cerca del 14% del Brix) y aumentaba a un maximo con una posicion que se movia durante la estacion de cosecha hacia el extremo superior del tallo de la caña (obteniendose un valor de 22,9% Brix en el ultimo nudo en el periodo final de observacion, el 11 de setiembre de 1978).

Los valores de pureza determinados a esta fecha fueron mas altos que el 90%, áun en el brix de los nudos de la base.

Otros cinco tallos mostraron anormalidades similares, aunque no en tal grado. Solamente en tallo de la planta madre mostró lo que puede ser considerado una distribución normal en la concentración del jugo. El otro caso se refiere a la distribución de la concentración del jugo observado a lo largo de los tallos que ha sufrido algun daño por la helada.

En estos tallos un valor bajo de 10%, cerca del 13% en algunos casos, fue encontrado en el jugo de los nudos más bajo. El Brix % incremento hacia la parte superior del tallo hasta valores más altos que el 21%. En algunos casos este fué un fenómeno masivo afectando una importante proporción de los cultivos comerciales, permaneciendo áun hasta el final de la cosecha de 1978.

CAUSATIVE FACTORS FOR THE OCCURRENCE OF CHLOROSIS IN SUGARCANE GROWTH IN RED LOAMY SOILS

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ABSTRACT

Causes of chlorosis in sugarcane grown in red loamy soils of Coimbatore were investigated. Different parts of healthy and diseased plants were analyzed for iron, manganese and phosphorus. Samples of red loamy (chlorotic), black cotton (healthy) soils and the irrigation water used were analyzed for various components. Effect of iron, manganese and sulphur sprays was studied on a chlorotic crop in a replicated trial.

It was found that the chlorotic leaves of the diseased plant contained significantly less iron whereas, the manganese content was maintained on par with the green leaves. There was indication of iron accumulation in the stem bearing these leaves. The soil analysis showed that the red loamy soil had available iron below the critical level and it was alkaline and calcareous. The irrigation water used contained a high level of water soluble salts, bicarbonates, chlorides, sulphates and calcium. Spray application of nutrients indicated that only iron, either as ferrous sulphate or as iron chelate helps in the recovery of chlorotic plants.

It is observed that high calcium carbonate reduces the available iron content of the soil and even whatever little iron absorbed by the plant accumulates in the topmost portion of the stem and sheath bearing the chlorotic leaves thus disturbing the Fe : Mn and P : Fe ratios in the affected stem and leaves. Methods to overcome the disease were suggested.

INTRODUCTION

Occurrence of chlorosis in sugarcane grown on garden soils of Tamil Nadu has been known for some years. It has also been reported from other parts of the country (De Rajat and Singh[7], Tomer *et al*[27]). Both plant and ratoon crops are affected at all stages of crop growth. The initial symptoms of chlorosis appear with the onset of the hot weather and increases thereafter. Sometimes there is a mild recovery, immediately after showers, but it recurs after sometime (Srinivasan[24]).

Sugarcane chlorosis in India have been attributed to various factors. Deficiency

of iron (Tomer *et al*[27]), deficiency of sulphur (Nagarajan and Sundararaj[17]), inactivity of iron caused by the deficiency of manganese (Srivatsava[25]) and also to two pathogens, nematodes and phythium (Srinivasan[24]).

The spread of the disease is quite rapid in the red loamy soils of Coimbatore district in the last few years. Hence, an attempt has been made to investigate the causes for this disorder so that appropriate corrective measures could be taken.

EXPERIMENTAL PROCEDURE

Samples of healthy and diseased plants of the variety Co 419 were collected from a replicated trial laid out at the Sugarcane Breeding Institute, Coimbatore The plots were manured at the rate of 210-60-75 kg/ha of N P K as urea, super phosphate and muriate of potash, respectively. Both nitrogen and potassium were applied in two equal and split doses at 45 and 90 days after planting. Superphosphate was added in a single dose at planting. Plant samples were taken when the crop was eight months old. Samples were separated into (a) stems bearing no leaves, those that bear green leaves, and chlorotic leaves (b) sheath of green and chlorotic leaves and (c) those with green and chlorotic leaves. The samples were cut into pieces with a brass knife and were oven dried at 80°C. The dried samples were powdered and used for the analysis of iron and manganese contents using method of Jackson[13], and total phosphorus using the method of Koeing and Johnson[14].

Soil samples at three depths (30, 60 and 90 cm) were analyzed for pH, organic carbon, water soluble, salts, water soluble calcium, free calcium carbonate, total sodium, total magnesium, available iron and exchangeable manganese. The irrigation water of the red loamy and black cotton soils was analyzed for pH, total soluble salts, carbonate, bicarbonate, chloride, sulphate, calcium and magnesium. Procedures outlined in A.O.A.C.[1] were followed for these analysis except for available iron, manganese and free clacium carbonate contents of the soil where the methods of Hesse[11], Jackson[13] and Piper[20], respectively, were used.

The usefulness of manganese, iron and sulphur as a corrective measure was evaluated in a field experiment. Plots from which plant samples were collected for chemical analysis have received the following treatments.

(a) Sprays of chelated manganese (Sequestene Mn — Disodium manganous ethylene diaminetetra acetate dihydrate) at the rate of 1 kg/ha

(b) Sprays of chelated iron (Sequestene 138 Fe — Sodium ferric ethylene diamine di O-hydroxy phenyl acetate) at the rate of 1 kg/ha

(c) Sprays of ferrous sulphate (0.5%) solution

(d) Sprays of sulphur at the rate of 2 kg/ha

(e) Control — water spray

In each case the same quantity of water was utilized with 1 ml of surfactive

TABLE 1. Iron*, manganese* and phosphorus contents of different parts of healthy and chlorotic sugarcane plant at 8 months

S. No.	Plant part	Fe(ous) iron (ppm)		Mn(ic) manganese (ppm)		P_2O_5—phosphorus (ppm)		Fe/Mn ratio		P/Fe ratio	
		Healthy plant	Chlorotic plant	Healthy plant	Chlorotic plant	Healthy plant	Chlorotic plant	Healthy plant	Chlorotic plant	Healthy plant	Chlorotic plant
1	Leaf										
	a) Green	151.6	191.9	124.7	106.2	2470	1710	1.22	1.81	16	9
	b) Chlorotic	—	80.9	—	127.2	—	2350	—	0.64	—	29
2	Sheaths of										
	a) Green leaves	75.0	59.60	161.8	216.6	1570	1150	0.46	0.28	21	19
	b) Chlorotic leaves	—	66.0	—	153.0	—	1860	—	0.54	—	28
3	Stem										
	a) Bottom (bearing no leaves)	62.2	56.1	36.1	39.5	1080	770	1.72	1.40	17	14
	b) Top (with green leaves)	100.0	61.7	46.6	30.4	2080	1340	2.13	2.07	21	22
	c) Top (with chlorotic leaves	—	112.5	—	77.1	—	3000	—	3.05	—	27
Between different parts of a plant	SE_d		18.2277		30.47		160				
	CD		37.2210		62.22		330				

** Determined calorimetrically. Fe as orthophenanthroline red ferrous complex and Mn as H MNO_4*

TABLE 2. Composition of black cotton (healthy) and red loamy soils (unhealthy)

Soil depth cm	pH		Organic carbon (%)		EC mm hos/cm (water soluble salts)		Water soluble calcium % (Ca^{++})		Exchangeable calcium (%)	
	Black soil	Red loamy soil	Black soil	Red loamy soil	Black soil	Red loamy soil	Black soil	Red loamy soil	Black soil	Red loamy soil
30	8.42	8.80	0.46	0.45	0.43	0.47	0.007	0.026	0.649	1.317
60	8.38	8.70	0.36	0.36	0.41	0.58	0.008	0.026	0.691	1.659
90	8.38	8.68	0.29	0.35	0.47	0.65	0.008	0.020	0.924	1.559

	Free calcium carbonate (%)		Total sodium %		Total magnesium %		Available iron (ppm)		Exchangeable manganese (ppm)	
	Black soil	Red loamy soil	Black soil	Red loamy soil	Black soil	Red loamy soil	Black soil	Red loamy soil	Black soil	Red loamy soil
30	3.8	5.1	0.0013	0.0015	0.791	0.686	2.133	1.144	23.5	21.9
60	3.8	5.1	0.0013	0.0014	0.949	0.781	2.144	1.311	24.0	16.6
90	3.9	5.5	0.0011	0.0018	0.965	0.859	1.775	1.088	11.4	12.3

TABLE 3. Composition of irrigation water used for black soil (healthy) and red loamy soil (unhealthy)

S. No.	Constituent		Water source for		
			Black soil	Red loamy soils	
				Bore No. 1	Bore No. 2
1.	pH		7.50	8.00	7.65
2.	E.C. mm hos/cm		1.03	3.00	2.31
3.	Total soluble salts	ppm	1379.5	4308.5	2954.5
4.	CO_3	ppm	Nil	Nil	Nil
5.	HCO_3	ppm	61.0	49.0	73.0
6.	Cl	ppm	82.0	652.0	400.0
7.	SO_4	ppm	35.5	330.0	131.0
8.	Ca	ppm	74.0	136.0	107.0
9.	Mg	ppm	50.5	77.5	67.5

agent. Treatments (b) and (c) were repeated twice at an interval of 7 days. Each treatment was repeated four times in a plot with an area of 30.5 sq meters. The number of healthy and chlorotic shoots were recorded before treatment and 15 days after. Per cent chlorotic plants was calculated. Treatments (a) and (b) made use of chemicals obtained from Ms. Tata-Fission Ltd. in Bombay, India.

RESULTS

Plant analysis

Data on iron, manganese and total phosphorus content of different parts of the plant are given in Table 1. The iron content of green plant was at a maximum in the leaves and top portion of the stem. In a chlorotic plant, more iron was found in the green leaves and also in the stem bearing the chlorotic leaves. The chlorotic leaves had significantly less iron than green leaves. Thus, there appears to be some impairment of iron movement within the chlorotic plant. The manganese content, on the contrary, was maximum in the sheath and leaves of green and chlorotic plants. The manganese content was the same both in chlorotic and green leaves. The Fe/Mn ratio was much affected in the chlorotic leaves As in the case of iron, the P content of green plant was maximum in the leaves. In the chlorotic plant, the stem bearing chlorotic leaves contained maximum P followed by chlorotic leaves and also their sheath. The P/Fe ratio increased considerably in chlorotic leaves followed by the sheath of chlorotic leaves and stem bearing these leaves.

Soil and water analysis

Data recorded on soil and water analysis are shown in Table 2. The data shows that the red loamy soil had higher pH and water soluble salts, mainly of calcium. There were more water soluble and exchangeable calcium, and free calcium carbonate contents in this soil. The concentration of these salts increased with soil depth. The available iron content of the red loamy soil was below the critical level, whereas, the exchangeable Mn content was far above the critical level and was on par with the black soil. The critical level of available iron was 2 ppm (Olson and Carlson[19]). That of exchangeable Mn was 3 ppm (Sherman and Harmen[22]).

The irrigation water used for the red loamy soil had higher pH, Ec and water soluble salts. Among the anions, the bicarbonates, chlorides and sulphates were predominant. Calcium was abundant in this sample (Table 3).

Data on per cent chlorotic plants per plot are given in Table 4. Of the nutrients sprayed, ferrous sulphate and iron chelate alone affected the restoration of green color in the chlorotic leaves within a fortnight. More plants turned chlorotic during this period in the control of sulphur and manganese treated plots.

TABLE 4. Effect of different micronutrient sprays on the recovery of sugarcane plants

No.	Micronutrient	% chlorotic plants per row	
		Before spray	15 days after spray
		(Mean of 4 replications)	
1	Control	53.8	67.0*
2	Sulphur	56.5	63.5
3	Manganese chelate	47.4	58.8
4	Iron Chelate	54.0	1.9
5	Ferrous sulphate	43.5	0.5
	SE d	NS	3.78
	CD		8.25

** Mean transferred values*

DISCUSSION

Several factors have been listed by Brown[5] as responsible for iron chlorosis in plants. He had stressed the fact that iron chlorosis is potentially a problem on calcareous soils. In these soils, the bicarbonates are produced by the reaction of calcium carbonate with CO_2 and water (Wadleigh and Brown[28]). The presence

of bicarbonates in the soil solution affects the iron distribution in the shoots. The irrigation water of red loamy soils also contribute to the bicarbonate content of the rhizosphere (Miller and Evans[15]). It is perhaps because of this that the available iron content of the red loamy soils was far below the critical level. It is known that in the presence of a bicarbonate, the respiration rate of root tips of plants which are susceptible to lime induced chlorosis, is much reduced (Miller and Thorne[16]) and that the cytochrome oxidase activity of root preparation is consistently less (Miller and Evans[15]). This may reduce the uptake of iron itself. Another view of the effect of bicarbonate on iron chlorosis is, in part, the inter-relationship between HCO_3, P, Ca and Fe in the root medium. The development of iron chlorosis is more related to P concentration in the nutrient medium or to that absorbed by the plant, than to HCO_3 concentration in solution. Greenwald[9] and Olsen *et al*[18], have observed that HCO_3 increases the solubility of phosphorus in solution. Thus, the HCO_3 ion has a double role in that it may increase phosphate availability and decrease the available iron supply. In addition to the effect of HCO_3 ion and P availability, the presence of high calcium in the soil solution makes the sugarcane plant absorb more P, as has been reported earlier (Taper and Leach[26]).

It was observed that the phosphorus on its entry into the chlorotic plants, accumulated in the top portion of the stem and fixed most of the iron, thus, blocking its movement into the leaf where it was mostly required. The Fe/Mn ratio, which is a very good indicator of their relationship, should be above 1:1. If it is 1:1 or less, iron deficiency or manganese toxicity appears (Humbert and Martin[12]). In the chlorotic leaves, it was found to be below this value so as to cause the deficiency. The P:Fe ratio, which is considered to be a useful index of the iron status of plants, was also high in the chlorotic leaves of sugarcane. Such high values of P:Fe ratio was obtained by De Kock[6] in mustard plants. Thus, the data on the soil and plant analysis and the results of spray application of nutrients clearly indicated that chlorosis of sugarcane grown on red loamy soils of Coimbatore is due to the iron deficiency, and not the manganese deficiency as reported by Strivatsava[25] on the calcareous soils (shallow black soils) of Utter Pradesh, India.

The problem is aggravated by the highly brackish water used for irrigation of the red loamy soils of Coimbatore. This is because the water table around Coimbatore has gone down to about 200 feet in the last ten years due to reduction in annual rainfall and to excessive depletion of underground water. One thousand ppm of soluble salts is usually considered the upper limit of good quality water for sugarcane cultivation. Further, Harley and Linduer[10] observed that constant use of brackish waters, relatively high in bicarbonates, for irrigation purposes, induces iron chlorosis.

Of the many methods suggested to overcome chlorosis in crops (Wadleigh and Brown[28]) selection of resistant varieties, application of iron chelates to the soil or spray application of ferrous sulphate, judicious application of phosphatic fertilizers and avoiding green manuring, appear to be practicable for sugarcane cultivation in calcareous soils of Coimbatore. Varietal differences were recorded in this Institute for this character (Shah[21]). Since chelates are not freely available in the market, spray application of ferrous sulphate appears to be the only way for the present. With highly immobile Fe, the newly emerging leaves need fresh

sprays and for complete recovery, repeated application of ferrous sulphate is essential.

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FACTORES CAUSANTES DE LA OCURRENCIA DE CLOROSIS EN EL CRECIMIENTO DE LA CAÑA DE AZUCAR EN SUELOS ROJOS-FRANCOS

K.M. Naidu, S. Ramakrishnan and K.V. Bhagyalakshmi

RESUMEN

Las causas por la ocurrencia de la clorosis en el crecimiento de la caña azucar en los suelos francos-colorados de Coimbatore fueron investigados. Diferentes partes de plantas sanas y enfermas fueron analizadas por la presencia de hierro, manganeso y fosforo. Fueron analizados por varios componentes, muestra de suelos franco-colorado (clorotico) y negro algodon (saludable) y tambien el agua de irrigacion usada. El efecto de las pulverizaciones con sulfatos de Hierro y Manganeso fueron estudiados en un cultivo clorotico en un ensayo replicado.

Se encontro que las hojas cloroticas de plantas enfermas contenian significativamente menos hierro, mientras el contenido de manganeso corria parejo en las hojas verdes. Habia indicaccion de acumulacion de hierro en las hojas de esos tallos productivos. El analisis de suelos mostro que el suelo franco-colorado tenia disponible hierro debajo del nivel critico y que era alcalino y calcareo. El agua de irrigacion usada en este suelo contenia altos niveles de sales solubles en agua, bicarbonatos, cloruros, sulfatos y calcio. La aplicacion por pulverizacion de nutrientes indicaron que solamente el hierro, ya sea como sulfato ferroso o como quelato de hierro, ayudaban en la recuperacion de las plantas cloroticas.

Se observo que el alto contenido de calcio reduce el contenido de hierro disponibles en el suelo y aun cualquier pequeña cantidad de hierro que es absorbida por la planta se acumula en la porcion superior del tallo y la vaina que soporta las hojas cloroticas disturbando asi los cocientes de Fe:Mn y P:Fe en las hojas y tallos afectados. Fueron sugeridos metodos para superar la enfermedad.

TIRES OR TRACKS IN CANE TILLAGE

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ABSTRACT

Availability and price trends of tractor fuel encourage sugar cane producers to intensify their search for more efficient use of field tractor power. A simplified analysis of two-wheel drive (2-WD), four wheel drive (4-WD), and track type tractors (TTT) are currently best suited and is outlined by physical parameters determined by power, speed and weight. Tractor efficiency, power efficiency, matching implement loads, owning and operating cost considerations, plus the effects of tractor and implement weight on plant root development are discussed.

Wheel tractors are well adapted to tillage, transport, landforming, cultivation, weed control and other applications where drawbar loads are medium to light and their mobility is a requisite. Current direct drive tract-type tractors are well adapted to application requiring high drawbar pulls, maximum fuel efficiency, minimum surface compaction and long life. There is a great need for more careful matching of tractor power, weight, and speed with implement drafts to obtain higher production at lower costs to help alleviate the pressures from mounting fuel and equipment costs while sugar prices are depressed.

INTRODUCTION

Many sugarcane producing countries do not have their own source of fossil fuel and feel the adverse impact of high costs of imported oil. Those countries having an abundance of fuel can now receive such a favorable price by exporting their surplus fuel. It becomes expedient for all cane producers to intensify their search for more efficient use of field tractor power.

Tractor users are often confused by conflicting recommendations concerning the type and size of tractor for specific applications in agriculture. Much of this confusion results from the:

1. Efforts to extend practices common in temperate climates where shallow rooted crops dictate tillage speeds up to 10 km/h (6.2 mph) with light draw-

bar loads, to other areas where deep rooted crops need deep tillage which is most efficiently accomplished at lower speeds and higher drawbar pulls.

2. Use of different power ratings including maximum engine, flywheel, power takeoff, drawbar or concrete, without clearly identifying which power is used on what surface, at what speed.

3. Users' lack of information concerning implement loads including accurate owning and operating cost data.

Experience during the past decade indicates that two–wheel drive (2-WD), four-wheel drive (4-WD), and track-type tractors (TTT) all have their place in our search for improved efficiency in producing food and fiber.

DISCUSSION

Parameters

Under normal tractive conditions, agricultural drawbar pulls below 3000 kg (6600 lbs) can be efficiently supplied by 2-WD tractors. However, if compaction, traction, or flotation is critical, it may be advantageous to use a 4-WD or a TTT for these low drawbar pulls. Selection of 4-WD or TTT for drawbar loads over

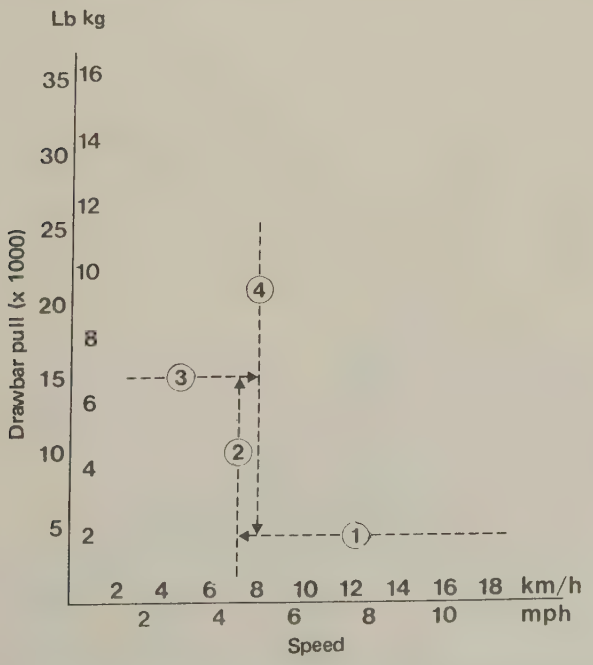

FIGURE 1. Speed and drawbar pull relationship of tired tractors.

3000 kg (6600 lbs) are usually determined by the speed of the work. Speeds up to 7 km/h (4.4 mph) favor the TTT where speeds over 8 km/h (5.0 mph) favor the 4-WD.

Basic information from the Manitoba Traction Tests (Friesen *et al*[4]), Bowers Rule (Bowers[1]), and years of field experience, were drawn upon for development of the following simplified analysis to be used as an aid in choosing the proper tractor for specific agricultural applications. Fig. 1 shows speed plotted on the horizontal scale and drawbar pull on the vertical scale. Arrow (1) is one parameter for rubber tired tractors operating at speeds down to 7 km/h (4.4 mph) at drawbar pulls not exceeding about 3000 kg (6600 lbs) to maintain reasonable service life. Arrow (2) indicates the lower practical limit of approximately 7 km/h (4.4 mph) where high drawbar loads can be maintained for a 4-WD tractor up to approximately 7000 kg (15,400 lbs). Today's 4-WD tractors capable of sustained drawbar pulls of 7000 kg must weigh over 16,5000 kg (36,000 lbs) to produce these high pulls working on average ground conditions. Rubber tired tractors of this weight create compaction problems in many heavy soils.

Where deep tillage is required for deep rooted crops, the TTT is more efficient because in these applications, high drawbar pulls are developed as indicated by arrow (3). For these pulls, minimum tillage speed is about 3 km/h (1.9 mph)

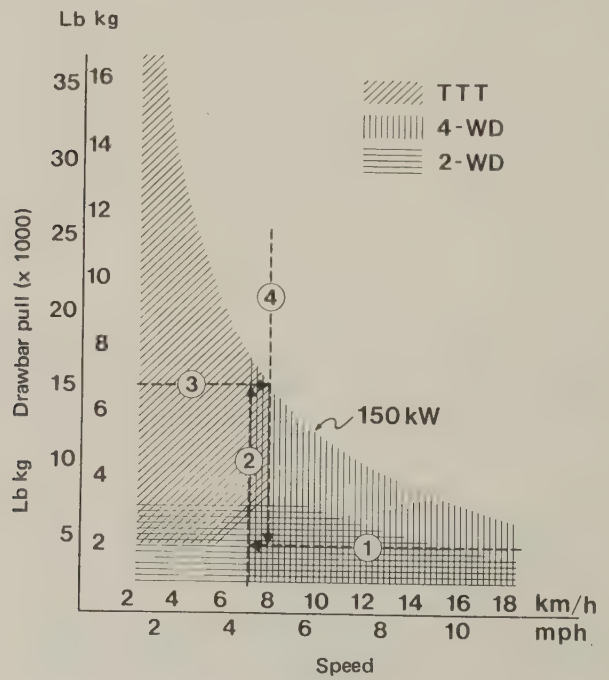

FIGURE 2. Work zones of 2-WD, 4-WD, and TTT.

to a maximum of about 8 km/h (5 mph). The TTT can develop drawbar pulls from 3000 kg (6600 lbs) to pulls in excess of 16,000 kg (35,200 lbs) at speeds below 8 km/h (5 mph) as indicated by arrow (4). These four arrows identify the approximate physical paramenters dictated by horsepower, traction, weight, and speed when choosing rubber tired or track type machines using current technology. The area bounded by the four arrows identifies a zone where application of 2-WD, 4-WD and TTT may overlap. In this zone, economic and convenience factors dominate the physical parameters.

Generally, it is impractical to own both rubber tired and TTT in sufficient quantity to perform every field application with maximum efficiency. To minimize capital investment, it becomes necessary to determine which type of tractor best fits the applications. In areas where traction and compaction are critical the TTT will dominate. Where speed and mobility are required, the rubber tired tractors will dominate. Drawbar power is a function of drawbar pull and speed. Practically all of today's agricultural tillage applications fall under 150 kW (200 h.p.) drawbar power. By superimposing a 150 kW curve on Fig. 1 and shading the areas in accordance with he parameters outlined, we have identified the three work zones for 2-WD, 4-WD and TTT in Fig. 2.

With today's technology, agricultural applications requiring an excess of 150 kW drawbar power are rare. require high return crops to justify the capital and operating costs.

Performance

Sugar cane growers are interested in the tons of sugar produced per unit area per month in relation to their investment over a period of years. Consequently, they desire a tractor that will provide the best tillage operations at the lowest cost over the life of the equipment. High performance for one or two seasons is inconclusive.

Tractive efficiency is affected by both motion resistance (Chancellor and Avlani[3]) and slip, making it imperative to use traction data for actual field conditions. In field applications, rubber tired wheel tractors can be expected to demonstrate a drawbar pull between 30% and 50% their weight at up to 16% slip without allowing a safety factor for service life. A major portion of motion resistance of an agricultural wheel tractor in tillage applications will be rolling resistance. A typical rolling resistance for a 10,000 kg (22,000 lbs) 4-WD is about 70 kg (155 lbs) for each short ton of operating weight in average tilled soil. By applying this rolling resistance to a 10,000 kg (22,000 lbs) tractor, we may calculate a drawbar pull of 770 kg (1,700 lbs) required to overcome rolling resistance only. This pull at 6 km/h (3.7 mph) requires about 13 kW (17 h.p.) drawbar power. Assuming the rolling resistance at 10 km/h (6.2 mph) becomes 21 kW (28 h.p.) drawbar power.

Demonstrable drawbar pulls in relation to tractor weight can be estimated by applying the traction factor listed below:

Soil Condition	2-WD 14-16% Slip	4-WD 14-16% Slip	TTT 3-6% Slip
Loose tilled or wet	0.29	0.37	0.52
Medium	0.40	0.43	0.54
Dry Firm	0.49	0.50	0.63

Temptation is great to match big wheel tractors with the biggest implements they can pull and still perform satisfactory tillage. Remember that to conserve drive train components, today's wheel tractors should not be counterweighted so continuous maximum drawbar power can be attained at actual speeds below about 7 km/h (4.4 mph). Optimum tractor performance of wheel tractors requires proper use of weight to keep slippage within economic limits. Guidelines for weighting wheel tractors in relation to p.t.o. horsepower and speed for more efficient operation on firm and tilled soils are as follows:

	Speed		Weight per pto h.p.	
Draft	km/h	mph	Kg	Pounds
Light	9.6	6	50-60	110-130
Average	8.0	5	60-70	130-155
Heavy	6.5	4	70-90	155-200

Slippage varieties widely with soil conditions, but should be kept below 16% for economical performance of wheel tractors. Increased ground contact provides the TTT with superior tractive efficiency, making it less susceptible than wheel tractors to adverse soil conditions. The TTT sprocket drives the tractor on metal rails making rolling resistance minimal; but, in place of rolling resistance, drag losses are encountered. This drag loss increases with speed. A guide to probable speed and drawbar pull capabilities of a TTT in relation to its operating weight is as follows:

Drawbar Pull	Probable Speed Range
70% of Tractor Weight	3.0-4 km/h (1.9-2-5 mph)
60% of Tractor Weight	4.0-4.8 km/h (2.5-3.0 mph)
50% of Tractor Weight	4.8-5 km/h (3.0-3.5 mph)
40% of Tractor Weight	5.6-6.4 km/h (3.5-4.0 mph)
30% of Tractor Weight	6.4-8.0 km/h (4.0-5.0 mph)
20% of Tractor Weight	Pulled at top speeds are rarely economical applications.

Power train components of direct drive TTTs withstand continuous pull at low tillage speeds without sacrificing life of drive train components. Therefore, economics dictate that TTTs be loaded as near capacity as terrain and soil conditions permit. It is relatively easy to match implement loads to a TTT by applying the drawer capability of the tractor in relation to its operating weight and desired tillage speed.

Power Efficiency

A practical guide for estimating wheel tractor drawbar power when matching implement loads has been developed by Wendell Bowers[1]. This "86% Rule" deviates a little from the Nebraska Test Data, manufacturers estimates, and years of field tests. The following factors are applied when p.t.o. power is considered as 1.0 and slip between 10 and 12%:

Power	Factor
Maximum Engine Power	1.16
Maximum p.t.o. Power	1.00
Maximum drawbar power on concrete	0.86
Maximum drawbar power on firm soil	0.74
Usable drawbar power on firm soil	0.63
Usable drawbar power on tilled soil	0.55
Usable drawbar power on soft soil	0.47

Using this rule to estimate usable drawbar power on firm dry soil, it would require about 275 kW (368 maximum engine) power in a 4-WD to deliver 150 kW (200 h.p.) usable drawbar power. A direct drive TTT can develop this same usable continuous drawbar power with about 200 kW (270 maximum engine) power through better traction and less rolling resistance.

Speed and its relation to timeliness is a major factor in selecting an agricultural tractor. In the haste to complete a tillage operation care must be exercised to assure that proper tillage is accomplished at reasonable costs. Selection of proper implement size is extremely important to utilize the optimum speed for the operation in an efficient power range for the tractor. Excessive speeds to achieve maximum area coverage often result in less depth of penetration producing a poor-seed bed, less safe operation, more wear and tear on the implement and higher fuel consumption. Applying average power efficiency (drawbar power divided by p.t.o. power) for all three Manitoba Traction Tests field conditions of 67% for the 4-WD, compared to 75% for the TTT, a fuel efficiency advantage for the TTT becomes readily apparent. These tests were of short duration and did not apply a factor to estimate continuous usable power.

Since the effect of speed on draft is large, it is of practical importance. An increase in speed increases draft. This trend has been sufficiently consistent so that quantitative relationships between speed and draft have been obtained using the formula from USDA Agricultural Handbook, No, 316 entitled, "Soil Dynamic in Tillage and Traction" (4). An example of this relation using a heavy duty plowing harrow in a heavy clay loam soil is shown in Fig 3.

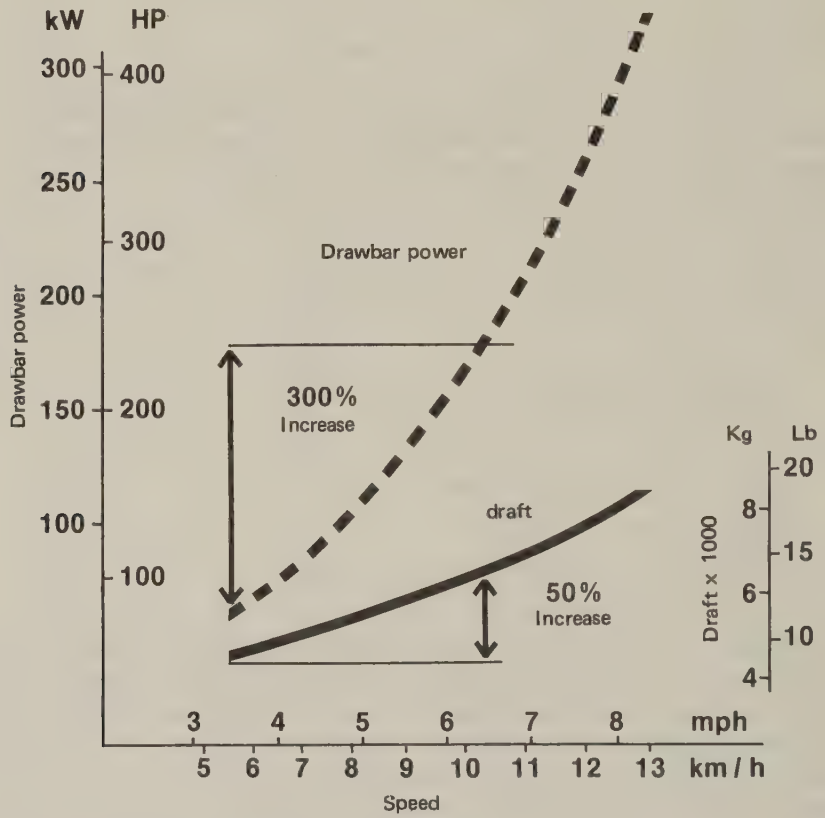

FIGURE 3. Deep plowing draft and drawbar power relationship with speed plowing in heavy clay loam soil.

For example a TRCH 10x36 heavy duty cane plowing harrow working in heavy clay soil requires approximately 4,500 Kg (10,000 lbs) drawbar pull at 4.8 km/h (3 mph) resulting in 60 kW (80 h.p.) drawbar power continuous. To pull this same implement in the same cane field *at the same depth* at 9.6 km/h (6 mph) will require about 6,800 kg (15,000 lbs) drawbar pounds pull resulting in 180 kW (240 h.p.) drawbar power. Is the extra production attained by doubling the speed worth tripling the drawbar power required? It will require 330 kW (440 h.p.) maximum engine power to deliver 180 kW (240 h.p.) usable drawbar power in a 4 WD tractor to pull the TRCH 10x36 at 9.6 km/h (6 mph) speed. An alternative

would be to use a 188 kW (250 h.p.) maximum engine drive TTT and pull a TRCH 20x36 plow at 4.8 km/h (3mph) speed to double the production through doubling the implement width rather than doubling the speed.

Speed in relation to implement wear is another factor to be considered in selecting a tractor and implement. Laws of motion and kinetic energy have been known for generations, but too few have related these basic laws with increased implement costs accompanying higher field speeds. An effect of speed on the energy input that results in abrasion and breakage is pictured in Fig. 4.

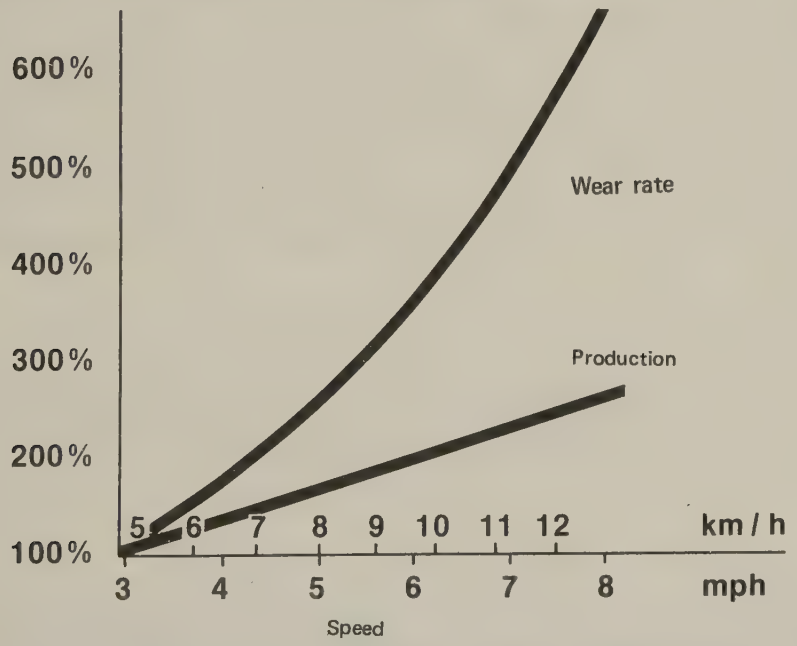

FIGURE 4. Implement wear vs production through increased speed

This adds credence to the following statements made by Larson[6].

(1) Raising implement speed from 4 to 5 mph has doubled implement repair costs, and

(2) Normal tillage with sweeps require about 4 horsepower hours per acre, increasing the tractor speed by one gear often increased the energy input by as much as 50%. (Larson[6]).

Operating too slow can result in poor pulverization whereas operating too fast increases the energy input with excessive pulverization inviting wind erosion and making soils more susceptible to crusting and sealing, affecting aeration and evaporation. Clearly, speed must be considered from viewpoints other than area

covered per unit time.

Compaction

Ground pressures of TTTs equipped for tillage with between 41 and 55 Pa (6 and 8 psi) are recognized as creating minimum compaction. Fallacies exist in the belief that we can eliminate soil compaction problems by simply reducing unit surface pressures through increased tire or track size. Improper width track shoes or unbalanced loading of TTT (Chancellor[2]) can double the computed average ground pressure, thus approximating surface ground pressures created by dual wheels on 4-WD tractors. However, with dual wheels, the 4-WD tractor usually compacts about twice the surface area as the TTT on each pass. Another factor often overlooked is the adverse effect on water infiltration and plant root development at greater soil depths. Increasing the area of contact to compensate for increasing the total load has not solved soil compaction problems at all depths. (Taylor *et al*[7]). Soil scientists are concerned about the irreversible field damage that may result from excessive compaction. Every precaution should be exercised to keep compaction at a minimum with all tractors, especially in heavy tropical soils.

Matching Tractor and Implement

As costs rise, fuel consumption will become more critical, as will the necessity of optimizing implement loads in relation to power, weight and speed. The basic relationships covered under tractive efficiency and power efficiency must be considered when matching a tractor and implement.

It is common to start with the implement that performs the tillage operation best suited for sugar cane production in your soil and climatic conditions. Actual measurement of the drawbar pull of the implement working at optimum speed and depth in your fields is the best way to determine drawbar pull requirements. Estimating implement draft is less accurate, but most often necessary. Manufacturers provide draft or drawbar pull guides for their implements. Agricultural Experimental Stations and University Extension Services have guides that estimate implement drafts at different speeds for soil conditions in their specific territories. The drawbar power required for pulling a tillage tool can be determined by using the following formula.

$$\text{kW (power)} = \frac{\text{kN (Draft)} \times \text{km/h (Speed)}}{3.6}$$

which is the SI version of the familiar

$$\text{hp (horsepower)} = \frac{\text{pounds (draft)} \times \text{mph (speed)}}{375}$$

Factors in Bowers "86% Rule" mentioned earlier need be applied to the resulting drawbar horsepower in field condition encountered to determine the p.t.o. or engine h.p. required in a wheel tractor. Weight of the wheel tractor can be determined by using the factors discussed under tractive efficiency derived from the Manitoba traction tests.

Matching an implement to a TTT is easier. When the drawbar pull is determined, compare it to the tractor specification sheet drawbar pulls to determine which tractor will pull the implement at the desired speed. Direct dirve TTTs can be expected to deliver usable drawbar powers between 72% and 78% of their p.t.o. powers depending on soil conditions. The estimated weight requirement of a TTT can be determined from the weight speed relationship reviewed under slippage and drag loss. Matching a TTT to its load is more precise and simpler to accomplish than with a wheel tractor. There is a general tendency to underload TTTs and overload wheel tractors. The basic fundamentals outlined in this presentation can be used as guides to improve utilization of investment in tractor and implements which lead to the next important consideration.

Owning and Operating Cost Considerations

Hourly owning and operating costs can vary widely and must be determined with local cost inputs. The principal owning cost is *depreciation* determined by subtracting the re-sale value from the landed cost and dividing by the service life in hours. Interest, insurance and taxes added to depreciation make up owning costs. The service life and hours used per year are major factors determining hourly depreciation. When dealing with capital intensive equipment, the hourly depreciation rate and residual value become major items in determining owning costs.

Operating costs consist of expenditures for fuel, filters, lubricants, grease, repairs, tire or tract maintenance, and operators wages. Tire and track costs can, under adverse soil conditions or improper application, be a substantial portion of operating costs making it extremely important to carry out good maintenance practices. There is no substitute for good reliable cost records to compare with work done and tons of sugar produced to aid in determining which field applications can be best accomplished with tractor and implement.

CONCLUSION

Current wheel tractors are well adapted to light tillage, cane transport, land forming, cultivation, weed control and other applications requiring speed and mobility. Current direct drive TTTs are well adapted to applications requiring high drawbar pulls, maximum efficiency, minimum surface compaction and long life.

Energy costs and low commodity prices are forcing careful review of field costs worldwide. There are interesting challenges and beneficial opportunities facing

us today. I hope the comments in this presentation will aid in analyzing your field tractor requirements and matching those tractors with implements to provide more sugar per acre per month at a lower cost in future years.

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LLANTAS O CADENAS EN EL CULTIVO DE CAÑA

Lyle G. Reeser

RESUMEN

La disponibilidad y la tendencia del precio de combustible hace que el cañero intensifique su busqueda de uso efficiente del poder del tractor en el campo. Un analisis simplificado de cuando debe usarse un tractor de traccion en dos ruedas (2-WD), traccion en 4 ruedas (4-WD) o de tipo de oruga (TTT) es establecido por parametros fisicos determinados por la potencia, velocidad y peso. Se discute la eficiencia de traccion, eficiencia de potencia, el implemento con la carga requerida, costos de posesion y operacion ademas de los afectos del peso del

Los tractores de ruedas se adaptan bien a la aradura, transporte, nivelacion de terrenos, cultivo, control de maleza y otros usos donde las cargas en la barra son entre medianas y livianas y su movilidad es un requisito. Los actuales tractores de oruga de transmission directa se adaptan bien para aplicaciones en donde se require alto tiro a la barra, eficiencia maxima de combustible, minima compactacion el la superficie y larga vida. Existe una gran necesidad de igualar la potencia, peso y velocidad de tractores y los implementos con el fin de obtener una produccion alta a costos bajos que alivien la presion del aumento constante de costos de combustibles y equipo, mientras los precios del azúcar continuan en depresion.

SOIL AERATION, NUTRIENT UPTAKE AND YIELD OF SUGARCANE AS AFFECTED BY TILE DRAINAGE

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ABSTRACT

A field drainage experiment was conducted in fine-textured Low Humic Gley soil under a sub-tropical climate to evaluate the response of sugarcane to tile drainage. Tile drainage treatments were six combinations of two depths of 1.2m and 0.8m below soil surface, and three spacings of 15, 20 and 25m. A surface drained plot was added as check. After a heavy rain, water table levels in all tile-drained plots decreased much faster than in the surface-drained check. Forty-eight hours after the rain, the water table dropped to at least 60 cm in the drained plots and to 21 cm in the check. Oxygen concentration in surface-drained plot never exceeded 5% in the upper 30 cm depth during the whole rainy season. In all the tile-drained plots, oxygen contents however, seldom dropped to below 10%. The root development, nutrient uptake and sprouting of ratoon crop were substantially higher in the tile-drained plots than in the surface-drained plot. Increases of 17%, 40% and 34% in yield of plant, the first and second ratoon, respectively, were found in tile-drained plots.

INTRODUCTION

As in most sugarcane growing areas in the world, the climate of cane plantations in southern Taiwan is characterized by a clear wet season and a relatively long dry season. More than 1200 mm of rain are received from May to October. The water table rises to the level close to soil surface because of the flat topography and the poor internal drainage. The presence of shallow water table may cause poor soil aeration and restrict the rooting volume. Consequently, oxygen deficiency can cause a reduction in water and nutrient uptake and the formation of toxic products in the soil and plants (Wesseling[5], Williamson and Kriz[6]). When such poor aeration condition occurs in the boom growth stage and persists for a long time, retardation of vegetative growth, and a decline in yield will result. Thus, the productivity of plantations with water table at high levels, is limited by excessive wetness.

To remove excessive water from the root zone, a good drainage system is needed. For some plantations with good internal drainage, surface drainage

should also be adequate. In areas with high water table, additional sub-surface drainage system is necessary. Tile drainage is not a general practice in Taiwan and so information on the response of sugarcane to sub-surface drainage was not available. In 1975, a field drainage experiment was conducted to evaluate the effect of sub-surface tile drainage on the growth and yield of sugarcane. The performance and its effect on soil aeration were also measured in the field.

MATERIALS AND METHODS

The tile drainage installation was located in Shin Juan Plantation near Annie Sugar Mill in fine textured Low Humic Gley soil. The ground surface is quite flat with an average slope of less than 0.2%. The soil has well-developed columnar structure containing high percentage of silt. The top soil was very compact, but deep shrinkage cracks were formed between the soil clods resulting in a relatively high hydraulic conductivity as measured in the field by auger hole method (Van Beers[8]). The aeration porosity measured under 100 cm tension indicated that the top 35 cm layer had the lowest effective porosity, while the layer of 70 to 102 cm had the highest porosity at 6.3%. The profile description of this soil is given in Table 1.

TABLE 1. Major soil physical properties in the experimental field

Depth cm	Mech. composition			Texture	Bulk density g/cm^3	Effective porosity %	Hydraulic* conductivity m/day
	Sand %	Silt %	Clay %				
0- 35	24	44	32	CL	1.75	2.73	4.6
35- 70	19	40	41	SiC	1.56	4.80	
70-102	28	54	18	SiC	1.52	6.30	
> 102	14	52	34	SiCL	1.51	4.86	

**Measured by auger hole method.*

The experiment consisted of the surface-drained only and the combination of surface-drained and tile-drained plots. Tile drainage treatments were six combinations of depths 1.2 and 0.8 meters below soil surface, and spacings of 15, 20 and 25 meters. Each of the six treatments consisted of four lines measured at 80 meters. Only the central two drains and the land area between the two were used to obtain experimental measurements. The schematic drawing of the tile lay-out for this experiment is shown in Fig. 1.

Slotted PVC pipe with 5.6 cm inside diameter and 2 mm thickness was used as laterals. A layer of 20 cm thick graveis acted as drain envelope on the top part of the pipe. All the drains were installed at 0.17% slope in the direction perpendicular to the main drain. After the tile were installed, the plots were smoothed several times. Sugar cane variety of T 160 was planted

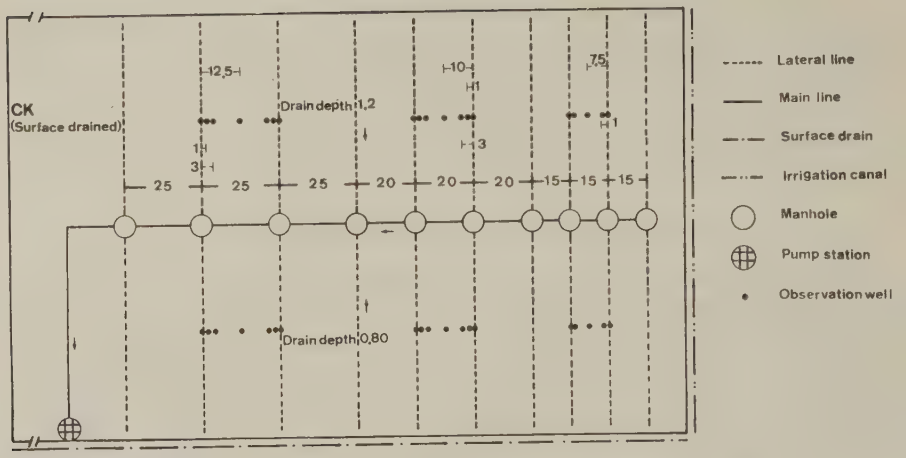

FIGURE 1. Field layout of the drainage system (unit on the figure in meter).

in 1.25-meter row spacing. Conventional cultural practices were used for all the drainage treatments.

Soil oxygen concentration was measured during the growth period of plant cane from September, 1975 to December, 1976 in both tile-drained and surface-drained plots in depths of 20, 30, 50 and 70 cm from soil surface. A special air sampling tube and a Beckman model 715 process oxygen monitor were used for measuring soil oxygen concentration (Yang and Lin[7]). Water table measurements were taken during the rainy season with 3.70 cm perforated PVC pipe installed as shown in Fig. 1. Leaf samples were collected every month in each treatment during the boom stage, for the analysis of N, P_2O_5 and K_2O concentration. Plant height and the number of tillers were measured periodically. Plant cane was harvested 18 months after planting and allowed to grow for two ratoon crops. At harvest, the length and the number of millable stalks and yield were determined. For ratoon crop, the sprouting percentage were measured one month after harvest. To determine the effect of drainage on sugarcane root development, soil samples were taken in each treatment by using 10x10x10 cm metal sampler in increments of 10 cm from soil surface to 60 cm. The roots contained were picked, washed and dried for comparison.

RESULTS AND DISCUSSION

Water Table Levels

Measurements of water table levels was made following the heavy rainstorm from July 2 to 5. In this period, a total rainfall of 230 mm was recorded. The results showed that water table levels midway between drains in all tile-

drained plots, decreased much faster than those in surface--drained plot (Fig. 2 and 3). Forty-eight hours after starting the measurement, the level of water table in tile-drained plots dropped at least 65 cm from soil surface. Only a 21 cm drop was observed in the surface-drained plot. Among the tile-drained treatments, 1.2 meter depth lowered the water table faster than the one at 0.8 meter depth. The narrower the spacing the more effective is the drain in lowering the water table.

The fluctuations of the water table midway between the tile-drains and the surface-drained plot for the whole rainy season starting from May to September, are shown in Fig. 4. Obviously, the water table levels in the tile-drained plot was consistently lower than the surface-drained plot. In more than half of the rainy season, the water table in surface-drained plot was higher than 50 cm. In August, the water table was maintained close to the surface for more than three weeks. Under such prolonged drainage condition, the growth of cane definitely would be affected. In the tile-drained plots, the water table did rise to the surface, but it dropped to 60-80 cm below the soil surface within 48 hours.

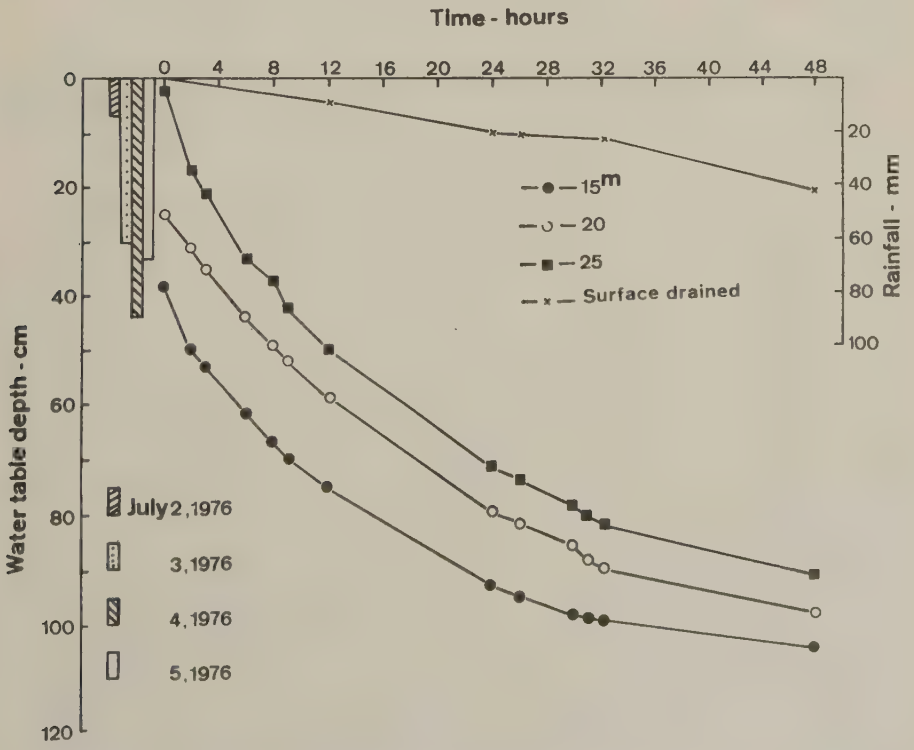

FIGURE 2. Water table positions for 1.2 m drain depth after rainstorm.

Oxygen concentrations

Fluctuations in oxygen concentration at different soil depth in the growth period of plant cane between September, 1975 to December, 1976 are shown in Fig. 5. Since the drainage efficiency between different treatments of tile-drained plots was basically the same, only the data obtained from tile spacing of 25 m with 1.2 m depth is shown. The figure indicates clearly that no difference in oxygen concentration between tile-drained and surface-drained plots were observed during the dry season. Oxygen concentration at the upper 30 cm soil layer was always 10% higher than in both treatments. Soil aeration therefore, is not a limiting factor to plant growth in this period. However, during the rainy season, the O_2 concentration in the surfaced-drained plot dropped markedly. It never exceeded 5% because of excessive water contained in the soil pores. While in the tile-drained plot, the soil oxygen concentration dropped after heavy rain or irrigation, but it returned rapidly to above 10% level. Such short-term deficiency may not cause great damage to cane plants. Yet, if oxygen deficiency persists for a long time as the case of surface-drained plot, root development, nutrient uptake and the growth of sugarcane would be affected. Experimental results shown by Carter[2] indicated that sugarcane can tolerate soil wetness for up to 7 days during the growing season without adversely affecting cane and sugar yield.

Growth and nutrient uptake

Excessive soil wetness caused by high water table during the boom stage

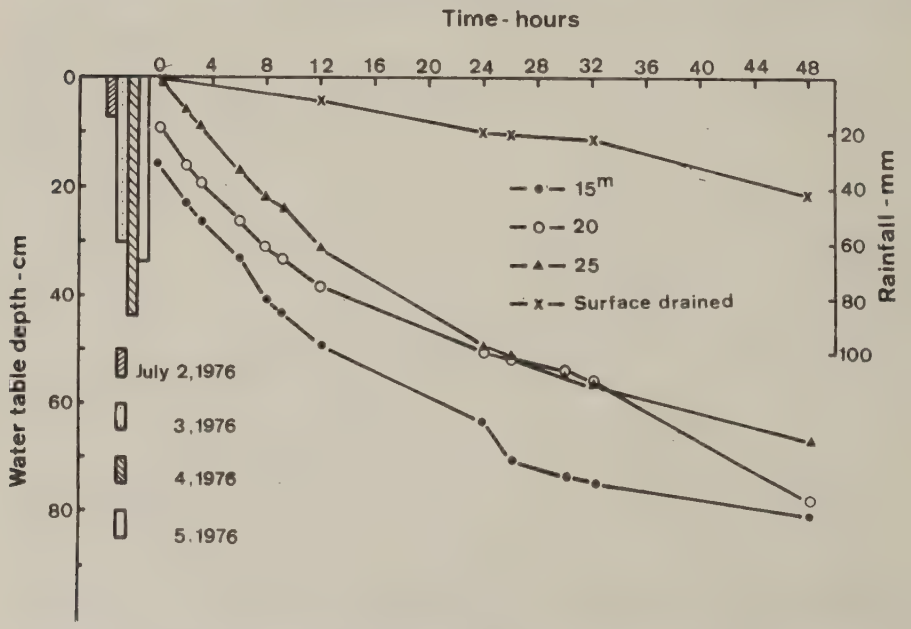

FIGURE 3. Water table positions for 0.8 m drain depth after rainstorm.

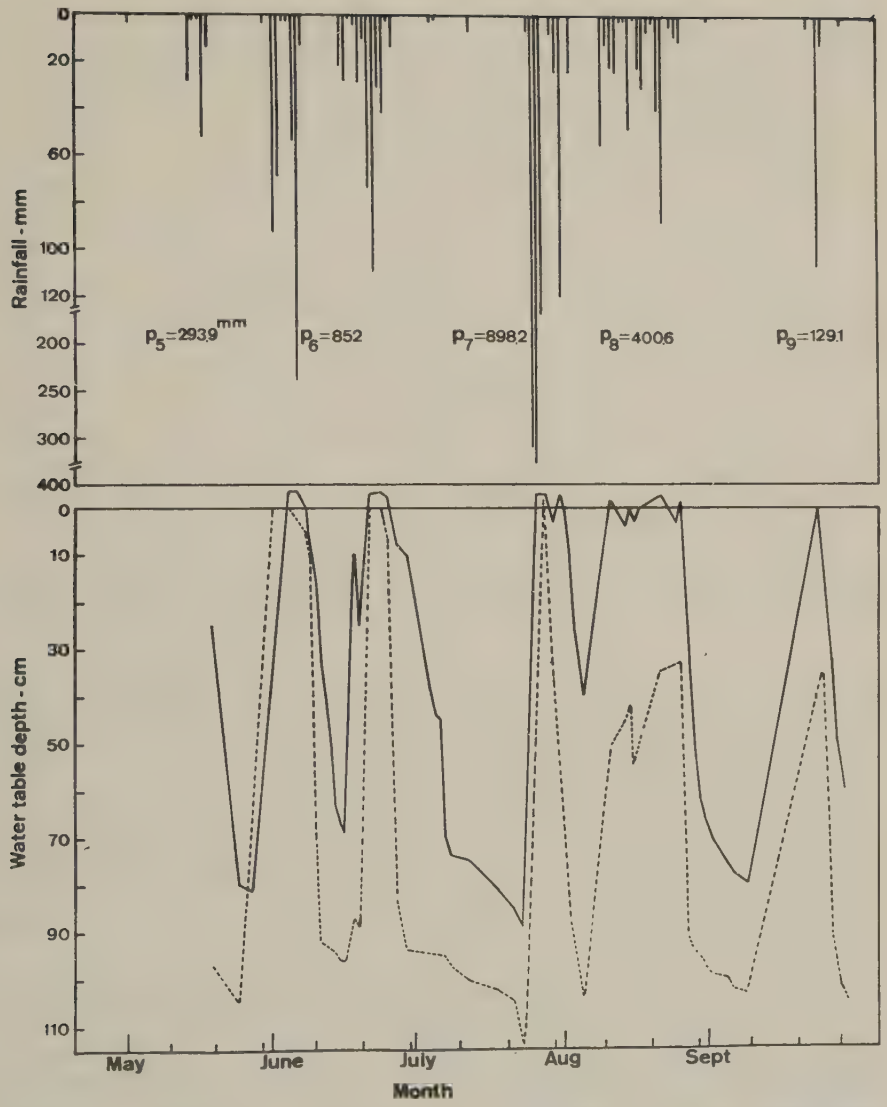

FIGURE 4. Fluctuation of water table in surface drained and the drained plots during the rainy season in 1977.

of plant and ratoon cane depressed both growth and nutrient uptake. The difference in stalk elongation between tile-drained and surface-drained plots was found to be more than 10 cm per month for June, July and August. At the end of the rainy season, the stalk length in surface-drained plot was 29 cm, 21 cm and 58 cm shorter than the tile-drained plots for plant, first ratoon and second ratoon, respectively (Fig. 6). Such growth retardation was caused mainly by oxygen deficiency which in turn, affected the nutrient uptake due to the fact that oxygen controls respiration and metabolism in

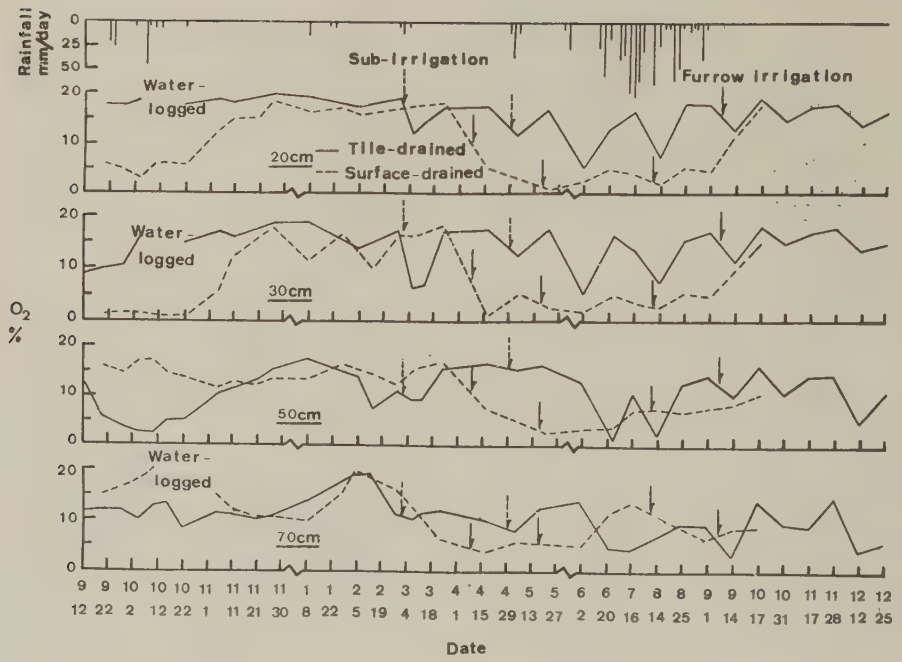

FIGURE 5. Fluctuation of soil oxygen concentration at 20, 30, 50 and 70 cm soil depth in the field with tile (with 25m tile spacing and 120 cm tile depth) and without tile in An-Nei.

TABLE 2. Nitrogen concentrations in cane leaf in relation to drainage treatments

Treatment	June			July			August			September		
	1st	2nd		1st	2nd		1st	2nd		1st	2nd	
	plant	ratoon	ratoon	plant	ratoon	ratoon	plant	ratoon	ratoon	plant	ratoon	ratoon
Surface drained	2.39	2.05	2.44	2.22	1.94	1.65	2.04	1.68	2.13	1.73	1.68	1.61
Tile drained												
15m x 1.2m	2.24	2.02	2.32	2.04	2.14	1.68	2.31	1.71	2.00	2.10	1.84	1.88
20m x 1.2m	2.31	2.11	2.34	1.96	2.10	1.63	2.22	1.89	2.10	2.04	1.81	1.88
25m x 1.2m	2.58	2.08	2.54	2.13	2.08	1.63	2.18	1.82	2.03	2.14	1.80	1.78
15m x 0.8m	2.43	2.17	2.30	2.04	2.09	1.68	2.22	1.80	2.03	2.10	1.84	1.77
20m x 0.8m	2.58	2.08	2.37	1.96	2.07	1.64	2.14	1.73	2.10	2.14	1.76	1.74
25m x 0.8m	2.45	2.04	2.24	2.24	2.04	1.64	2.14	1.89	2.06	2.14	1.90	1.74

roots of intact plants (Grable[4], Wesseling[5]). As shown in Table 2, the nitrogen concentration of +1 leaf in the surfaced-drained plot decreased steadily from the start of raining season in June to the lowest level in September. Although the nitrogen deficiency was recovered to the same level as the tile-drained

plot in October, it was too late for cane growing in surfaced-drained plot to catch up with normal growth since the boom stage has already passed. The uptake of P_2O_5 and K_2O showed less response to drainage condition. There was no significant difference between tile-drained and surface-drained plots.

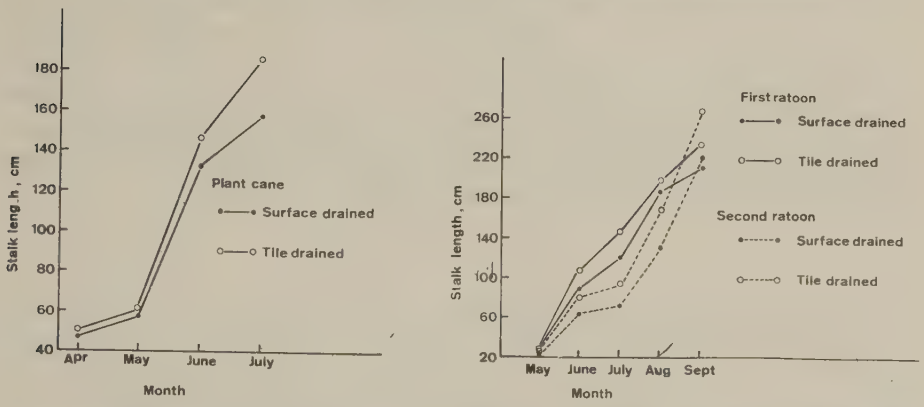

FIGURE 6. Effect of tile drainage on stalk elongation of sugarcane during the booming stage.

Root development

Root growth and activity were closely related to the aeration status in the root zone. Root system in tile-drained and surface drained plots were examined after cane was harvested. The root system in Fig. 7 shows that root density in tile-drained plot was considerably higher and roots could penetrate to a depth of 80 cm below soil surface. In surface-drained plot, less root proliferation was observed and penetration depth was restricted to 60 cm. In addition to visual examination, roots in 1,000 cm^3 volume of soil in each 10 cm segment were washed and weighed for quantitative determination. The results as shown in Fig. 8 incidate clearly that total dry root per unit soil volume in tile-drained plot was much higher than that in the surface-drained plot. A total dry weight of 2.59 g was contained in 6,000 cm^3 soil volume in tile-drained area and only 0.4 g was measured in the same volume of soil in surface-drained plot. The extensive and deep root system explores a large soil volume for water and nutrients. During the dry season, the deep roots may withdraw water from the capillary fringe of ground water. If the root development is inhibited because of poor drainage such as in the surface-drained plot used in this study, cane growth may suffer from water shortage at later period of drought when irrigation is not applied properly.

Sprouting of ratoon crop

The sprouting of stubble crop is considered critical for achieving a successful ratoon production. It determines not only the density and the uniformity

of crop stand but also relates indirectly to the planting expenses which include the labor cost for re-planting. Poor sprouting of ratoons is always a serious problem in areas with high water table in Taiwan. Installation of tile drainage system not only increases the yield of plant cane but also improves the sprouting of stubble crop and thus the ratoon yield. The average sprouting percentage of first and second ratoon in the tile-drained plots were 17% and 33%, respectively. These values were higher than the surface-drained plot (Fig. 9). The treatments with deeper drains, especially the treatment of 25 x 1.2 meters, had higher sprouting rate than the shallow drains. The higher sprouting percentage of ratoon crop in tile-drained plots may not relate to soil aeration but to the deep and highly proliferated root system since harvest is in the dry season.

Cane yield

This experiment was continued for 3 crop years. The plant cane was harvested in February, 1977. The first ratoon in February, 1978 and second ratoon in February, 1979. The yield data are listed in Table 3. Because of the improved aeration status in the root zone, the number and the length of millable cane stalks, and the cane yield were higher in the tile-drained treatments. The yield of stubble crop responded more sensitively to drainage condition than the plant cane because of the relatively short growth season. On the average, plant cane, first ratoon and second ratoon in tile-drained plots yielded 17%, 40% and 34%, respectively, more than that in surface-drained plot. In the rainy season of 1977, the boom stage of the first ratoon, an extremely high rainfall of 25.73 mm occurred causing serious water logging condition. Typhoon Thelma hit Taiwan in July and damaged sugarcane in experimental areas especially in the treatments of 20 m x 1.2 m and 20 m x 0.8 m. As a result, the yields from these two treatments were relatively lower than normal.

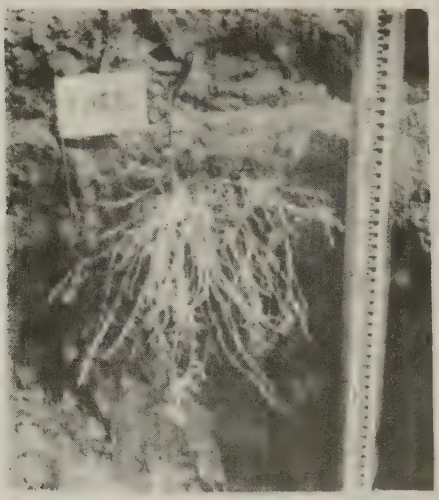

FIGURE 7a. Surface drained.

FIGURE 7b. Tile drained.

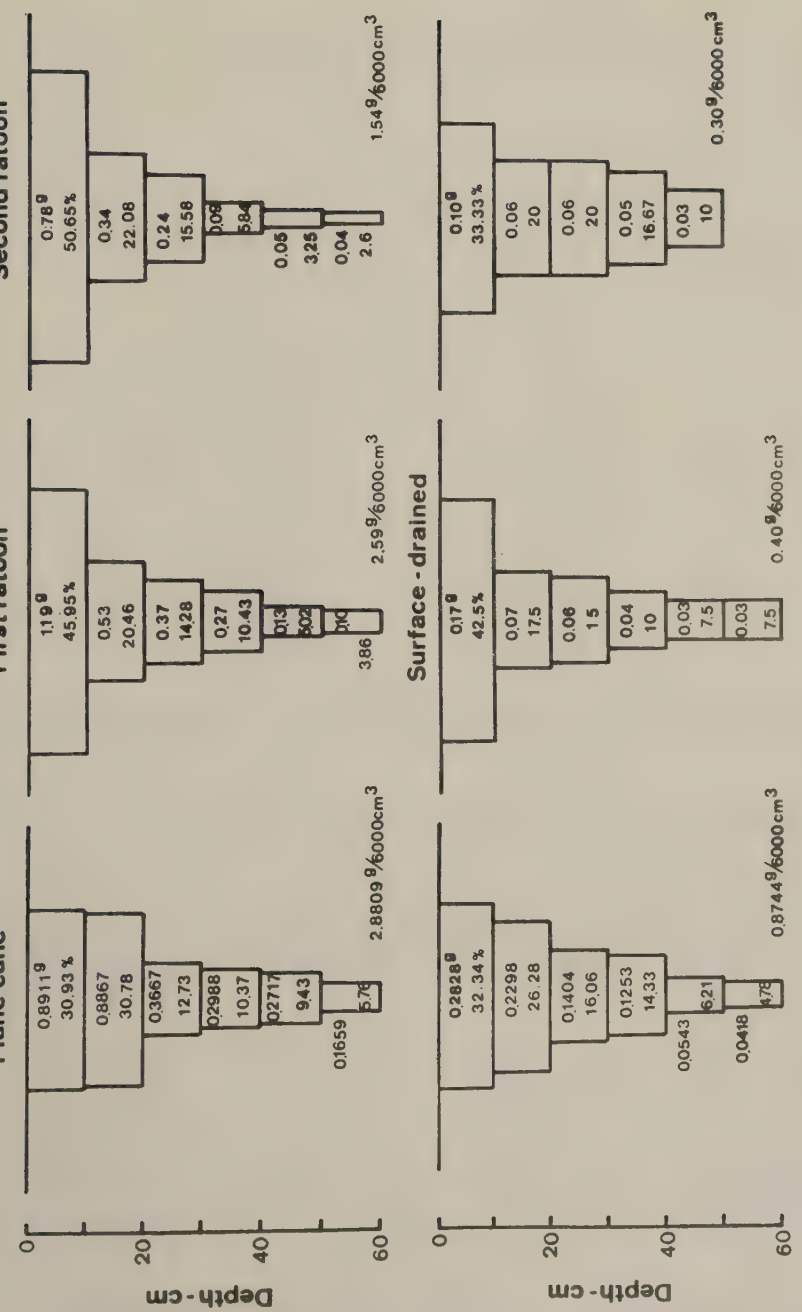

FIGURE 8. Root distribution in tile drained and surface drained plots

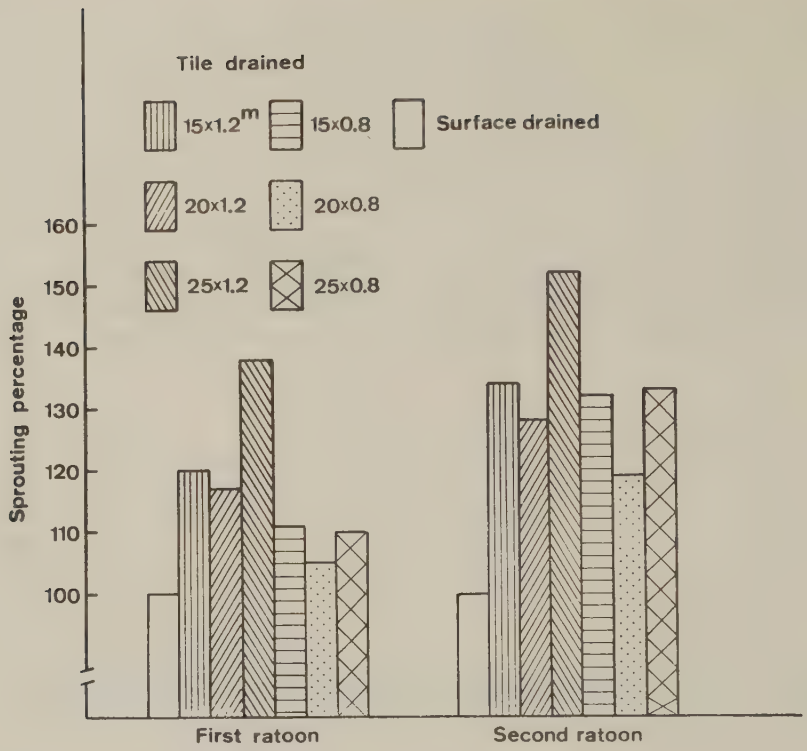

FIGURE 9. Effect of tile drainage on the sprouting percentage of ratoon cane

TABLE 3. Sugarcane yield as affected by drainage (Ton/ha)

Treatment	Plant cane	First ratoon	Second ratoon
Surface drained	113.6 (100)	70.894 (100)	65.895 (100)
Tile drained			
15m x 1.2m	135.3 (119)	97.684 (138)	84.421 (128)
20m x 1.2m	134.9 (119)	87.895 (124)	89.842 (136)
25m x 1.2m	130.7 (115)	97.895 (138)	93.368 (142)
15m x 0.8m	133.9 (118)	108.157 (153)	90.842 (138)
20m x 0.8m	130.4 (115)	95.947 (135)	87.842 (133)
25m x 0.8m	130.8 (115)	107.737 (152)	93.842 (142)

The difference in yield between tile-drained treatments was irregular and not significant. Such small difference in yield between treatments can be explained by the fact that all the drainage treatments, irrespective of drain depth and

spacing, were sufficient to improve aeration condition in the root zone during the rainy season.

Despite the fact that many experimental results from other countries (Camp and Carter[1], Escolar and Allison[3]) showed an increase in sugar yield after installation of sub-surface drainage system, no relation was found between sugar yield and drainage in Taiwan. Probably, this is because of the climatic condition. During the harvest season, the weather was relatively cool and dry which was favorable for sugarcane ripening. Drainage problems occurred only in the rainy season between May to September which was the booming stage for cane growth. Therefore, improving drainage can only increase the per unit area cane production but not the sucrose percentage.

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EFECTOS DE DRENAJE PROFUNDO EN AERACION DE SUELOS, ABSORCION DE NUTRIENTES Y RENDIMIENTO DE CAÑA DE AZUCAR

S.J. Yang and P.L. Wang

RESUMEN

Se llevó a cabo un experimento de drenaje de campo en terreno de textura fina y humedad baja en clima sub-tropical, para evaluar los efectos de drenaje profundo en caña de azucar. El drenaje profundo consistió de seis combinaciones de dos profunidades – 1.2 y 0.8 metros bajo la superficie del terreno, y tres espacimientos de 15, 20 y 25 metros. Para comprabación se añadió un lote con drenaje de superficie. Después de lluvias fuertes, el nivel freatico en todos los lotes con drenaje profundo disminuyeron mucho mas rapido que en el lote para comprabacion con drenaje de superficie. Cuarenta y ocho horas despues de la lluvia, el nivel en lotes con drenaje profundo bajo por lo menos 60 cm, mientras que en el lote de comprobacion bajo solamente 21 cm. Durante toda la temporada de lluvia concentracion de oxigeno en el lote con drenaje de superficie en ningun excedio 5% en los 30 cms de profunidad superiores, pero en terrenos con drenaje profundo el contenido de oxigeno raramente bajo a menos de 10%. En terrenos con drenaje profundo el desarrollo de la raiz, la absorcion de nutrientes y el brote de retoños fue substancialmente superior a los resultados que se obtuvieron en terrenos con drenaje de superficie. En terrenos con drenaje profundo hubo un aumento de 17%, 40% y 43% en la produccion de plantas, primer y segundo retoño respectivamente.

RAINFALL AND FROST MODELLING FOR SUGARCANE SYSTEM SYNCHRONIZATION IN PAKISTAN

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ABSTRACT

Meteorological models for rainfall and frost were studied to synchronize the operational policies of the mill and crop harvesting policies. For rainfall amounts, the weekly lag-one serial correlation coefficient was 0.52, significant at 99% level of probability; therefore a lag-one Markov chain model with the principle of Monte Carlo technique was used for rainfall data generation. The rainfall data generated with technique when compared with historical data indicated close agreement for mean, standard deviation and skewness coefficient, although the model was not developed to preserve the skewness. The lag-one serial correlation coefficient computed from generated data were in good agreement with those computed from the historical data. For frost, the correlation coefficient was not computed. Due to heat storage processes of the atmosphere, it was assumed that frost data can also be generated with a lag-one Markov chain. The data generated with this technique when compared with the historical data indicated consistency of mean and standard deviation, but it did not preserve the skewness coefficient. This study indicates that the Markov chain can be used effectively for rainfall and frost data generation, both elements having particular importance to sugarcane rendement and yield in irrigated districts of Pakistan.

INTRODUCTION

The irrigated sugarcane districts of Pakistan have great production potential with year-round radiation, deep alluvial, medium textured soils and extensive irrigation facilities to support sugar cane growth (Ayub and Early[3]). Several constraints, however, hinder sugarcane production and these include salinity accumulations, a water table approaching the soil surface, an extensively over-committed irriga-

tion water supply, high potential evapotranspiration rates causing high irrigation demands, a low annual rainfall and frequent frost occurrence in the early calendar months of the year. The latter two meteorological elements, rainfall and frost, are two stochastic components of the environment of sugarcane production, the quantification of which directly influences tonnage yield as rainfall in monsoon season substitutes for irrigation and rendement and as frost influences maturity during the cool harvest season. Both of these elements can be incorporated in a larger, overall management model for a sugarcane district as per the work of Aste-Tonsman[1] and Early[6].

Review of Past Modelling Research for Rainfall Events

Caskey[5] indicated that the rainfall probability distributions were closely approximated by a simple Markov chain model, consisting of a 1st order Markov chain and 2x2 transition matrix (wet and dry days). Comparison of pure random and Markov chain probabilities indicated that a Markov chain model was more reasonable than pure random assumption. Gabriel and Newmann[8] studying the succession of wet and dry days showed that a two state (wet and dry) Markov chain was a good model for representing this dichotomized process, indicating the probability that a subsequent day (1+1) will be wet or dry and is clearly dependent upon the event which occurred on the previous day (t). Wiser[13] found that the fit of a simple Markov chain model was unsatisfactory and proposed a modified Markov probability model using four modified Urn models as special cases with the desired characteristics and reducible to a simple Markov chain model. The modification was done by allowing the content of an Urn to vary in a specified way during a sequence of draws of balls of the same color from the Urn. When the sequence is terminated by drawing a ball of opposite color, the content of the Urn is restored to its initial state. He concluded that modified models were superior to a simple Markov model, in some cases which reflects the conditions when presistence plays a more important role than that assumed in the simple Markov chain model.

Hopkins and Robillard[10] approximated the pattern of rainy days over a 45-year data for the six-month growing season (April-Sept.) by using a simple Markov chain model. First, they calculated the proportional frequencies of occurrence of dry and wet days according to previous one or two day events and found dependency of second order. Secondly, they used a two state transition matrix for each month and concluded that Markov chain models oversimplify conditions in two respects. First, the trends in transition probabilities guaranteeing the observed seasonal precipitation pattern must actually occur continuously rather than the discrete monthly steps; hence the system must be non-stationary even within the months. Secondly, the Markov chain model ignores the different origin of precipitation which were the cause of the errors of the model.

Feyerherm & Bark[7] considered the difference in the use of a first order

Markov chain for estimating the probabilities for sequence of wet and dry days. These probabilities were found to have a dependence on the state of the previous day, but only a slight dependence on the state of the day before. The probabilities of sequence of wet and dry as calculated from the observed data were compared with those of the independent, 1st order-dependent, and 2nd order-dependent probabilities. It was concluded that difference between them was negligible and that a 1st order Markov chain model was adequate for computing probabilities for short sequences.

Todovic & Woolhiser[12] aimed at finding an explicit expression for the probability distribution of the total amount of precipitation, S_n, during a period of n days. Under the hypothesis that total precipitation for K wet days in a period of n days long is independent regardless which of these K days were actually wet and which of the (n-k) days were dry, they showed that

$$P(S_n \leqslant s) = P(N_{n=o}) + \sum_{v=1}^{n} P(S_v \leqslant s)(N_n = v)$$

where N_n is the number of wet days in an n-day period and sv is the total amount of precipitation for v wet days. P ($s_v \leqslant s$) was evaluated assuming that P ($S_1 \leqslant s$) $= 1 - e^{-}$)[5], i.e., the amount of rainfall of wet day in exponentially distributed random variable. They further assumed that rainfall depth on different wet days were independent, therefore s_v is the sum of v independent exponentially distributed random variables and thus have a Gamma distribution. P ($N_n = v$) was evaluated under two hypotheses: 1) there is no serial dependence in the sequence of wet and dry days, N_n is assumed binomially distributed and 2) the sequence of wet and dry days follows a two state Markov chain, hence the results of Gabriel and Newmann[8] are applicable. They found that Markov chain exponential model was superior to the binominal-exponential model, an indication that precipitation can not be treated as a succession of independent events. It appears that a new class of model is at hand if one assumes that the dry wet condition of day i+l depends on conditions of day i and that the amount of precipitation on day i+l also depends on the measured depth on day i; the way to proceed is to divide the range of observation in n $>$2, states rather than having only n = 2. An nxn transition matrix can then be estimated and the concept of Markov chain again applied.

Kharal & Henrich[11] used the n state Markov chain to model the daily rainfall and considered the process to be stationary for each month, i.e. the year was divided in 12 seasons. The range for daily rainfall depth was divided into 14 intervals. Therefore, 13x14 = 182 transition probabilities must be estimated for each season. They did not, however, attempt to fit the analytical distribution to conditional probabilities of the transition matrix. Whenever a state was reached, the mid-point of the corresponding interval was assigned as the general rainfall depth. They observed that any Markov chain approach suffers from the opposing effects of the need for a large number of states (to increase precision) and the explosion of the number of

the transition probabilities which must be estimated. Analytical distribution can not always be fitted to alleviate the problem.

Strictly speaking, the set of transformed observations does not constitute a random sample because of the persistence in the data and the lack of negative values. Therefore, the observed data which was not standardized and persistence was included by treating the series as a Markov chain model of lag one.

Frost Day Analysis and Generalization Techniques

The same principles that apply to wet and dry day analysis with the two state Markov chain is applied to the frost day and non-frost day. This is done by simply defining a frost as one with a minimum temperature less than 0°C or 32°F. Several rainfall criteria defining wet days were used and the probabilities of Markov chain were considered to be constant for each month. The results were satisfactory for all defining criteria.

System Synchronization Applications

Guise and Ryland[9] used quadratic programming to optimize the scheduling of production in Australian sugar mill with the aim to maximize the profit, subject to the limit of mill processing capacity, cane availability, sugar production in peak periods, fixed price and cost constraints. Aste-Tonsman[1] determined optimal harvest and irrigation policies for sugarcane production. The techniques used include a modification of the Simplex Algorithm of linear programming, utilized at three levels of planning and decision making. Early[6] developed a simulation model using the principle of Markov chain with a crude Monte Carlo procedure to determine the effect of alternate irrigation policies, irrigation capacities and milling capacity constraints on the production of sugarcane in the Philippines.

Each application has a particular set of environmental circumstances that must be considered, but the application toward synchronization or provision of a steady cane supply from field to factory with optimization on net economic returns to the district is the common goal of each research activity (Ayub[2]).

MATERIALS AND METHODS

In designing a system, models are needed. It is not advisable to construct a model based solely on the historical data, as the system is designed for the future sequence of events, and not for the past. Moreover, the historical data available are generally not sufficient to represent true population of input. Therefore, the generation of data is required for system designing or system performance studies, so that the model can be used with satisfactory confidence in the analysis. For the sugarcane system, climatological models of rainfall and frost are needed. The models are required to be practical and representative of actual climatological

events. The production models and mill performance models are also required to synchronize the field and milling operations.

Climatological Models

The actual models proposed are representative of those that are stochastic in nature. The aim of such models is to simulate as likely a sequence of events as possible, based on historical data. The harvested sugarcane is a perishable commodity; storage is not permitted between weekly time periods. Moreover, the irrigation system in Punjab is "WARABANDI" which means a farmer gets irrigation water once a week. Therefore, the time unit selected is week to observe the effect of rainfall and frost on the tonnage and rendement yield of sugarcane type of data used.

An extensive meteorological record from 1914-1975 was available. Rainfall data from a 20-cm standard non-recording rain gauge were obtained. The data from 1914-1970 were recorded in in/day, while from 1971-1975 were recorded in cm/day. The amount of daily rainfall was observed at 08:00 a.m. For the previous 24-hour period, the data for temperature was obtained from a maximum and minimum thermometer, and was recorded daily in $^{\circ}$F.

First order Markov chain was considered to be adequate to generate the data for rainfall and the frost. The first order or lag-one model for rainfall was justified by computing the auto-correlation coefficient, which is a measure of association within the series. The computed values of auto-correlation coefficient were obtained from 210 values (i.e. 4 years), as 50 to 300 values are suggested as an optimum number for computational purposes. The lag-one stationary transition probability matrices were estimated from the historical record. As the data available were on daily basis, the daily rainfall was summed up into weekly rainfall. The accumulated weekly rainfall series were grouped into n+1 states, providing an open class for the largest rainfall. The following example shows the limit of transition matrix. A (9x9) matrix was finally used.

The class limit of the transition matrix were

Depth of rain	*Corresponding class limit*
0.00	Dry
(0.01 – K_1)	1 to K_1 – 1
(K_{n-1}, cc)	(K_{n-1} to cc)

For frost, the correlation coefficient was not computed due to complexities involved. It was assumed that lag-one Markov chain model can also be used for

frost data generation. The number of frost days in each week were summed together, and the state of the transition matrix was determined by the number of the frost days. A (7x7) matrix exists if frost occurs continuously. The state presenting matrix of historical data was then subjected to frequency distribution. Frequency for each particular state for groups depended upon the states of the preceeding weeks' event. These probabilities when accumulated successively gave rise to contional transition probabilities matrices.

Procedure for Data Generation

1) The initial conditions were given for time period T, from some discrete meteorological observation in the record.

2) The time counter was increment by one week $T = T + 1$

3) The rainfall amount class for the current period T was determined, so with the transition probabilities for rainfall states and frost states for the discrete stationary Markov chain, as determined by enumeration from historical rainfall and temperature record.

4) A random number between zero and one was generated. The class of the random event in the transition probability matrix of random event for the week of the rain year was determined by comparing the random number to the cumulative probability for the category of the previous week. Corresponding to period T, the position of random decimal number, and the class for the event T+1 was determined. This method is in effect, the crude Monte Carlo procedure described by Buras[4].

RESULTS AND DISCUSSION

Rainfall Model

It is assumed that weekly rainfall is a time series of accumulated rainfall of daily time series. The rainfall amount of a week is dependent on the rainfall of the week before. The assumption is justified by computing the auto-correlation coefficient for different lags (Fig. 1). The graph of auto-correlation coefficient versus lag called a correlogram, clearly indicates that lag-one is significant at 99% level of probability with an upper confidence limit of +0.152 and a lower confidence limit of −0.162. Other lag confidence limit tests were not made in this analysis. These values were neglected with the assumptions that under the study, the highly significant results for lag-one were sufficient for the modelling of the general physical phenomenon. Moreover, the present event can affect the succeeding event, but its effect on the fourth area of subsequent events cannot be explained at this time.

After selecting the Markov chain model, conditional probability transition

matrices were estimated by using 61-year historical daily rainfall data which were assumed to weekly rainfall data. The transition matrices were a series of lag-one multistate matrices. The different states of the matrices correspond to the different range of rainfall amount of the week. The threshold values to divide the states were chosen randomly, with the assumption of uniform distribution of rainfall within the week.

The number of states of the matrices were determined by looking at the performance of the model in generating rainfall sequences that should reproduce certain statistical parameters of the historical data. By trial, 9 x 9 matrix was selected as the best one. The threshold values for different states of matrices are tabulated in Table 1.

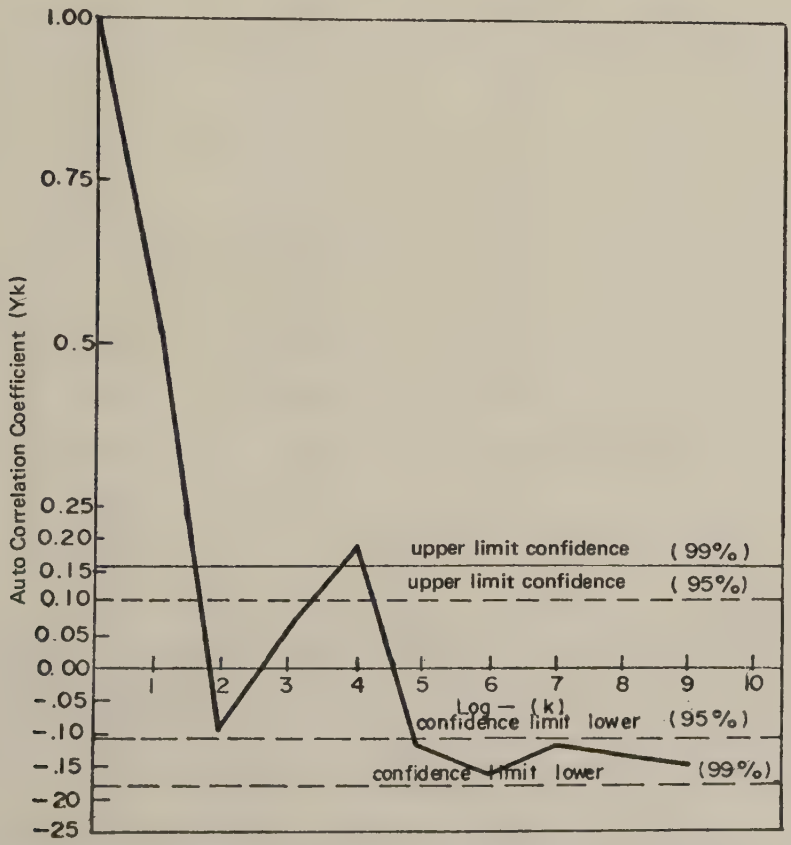

FIGURE 1. Correlogram of Historical Rainfall Data (212 readings)

In order to determine the transition matrices, data were generated for the different sizes of transition matrices. The criteria to choose the best matrix was the mean and the standard deviation weekly rainfall amount as the statistical para-

meters. These parameters were chosen because they were rather difficult properties of the series to reproduce.

The trial for selection of states of the matrix was started by 5 x 5 transition matrices. The above-mentioned statistical parameters were compared with historical series and the generated series. The number of states of the matrices were increased incrementally one by one up to (9 x 9) including the matrices. The last sets (9 x 9) were chosen because they reproduced the statistical properties closest to the historical data. An example matrix is presented in Table 2.

TABLE 1. Threshold values of rain for different states

State	Initial reading	Final reading	Range
1	0.0	0.0	0.0
2	0.01	0.50	0.50
3	0.51	1.25	0.75
4	1.26	2.25	1.00
5	2.26	3.75	1.50
6	3.76	6.00	2.25
7	6.01	9.50	3.50
8	9.51	14.75	5.25
9	14.76	0.0	0.0

Frost Model

The development of the model requires 3 assumptions. First, the daily frost series can be regarded as a sequence of two events, i.e., frost day and non-frost day. Secondly, the weekly frost series which is obtained by accumulating the frost days in each week has a significant first order persistence. Thirdly, a frost day is defined as a day for which the value of observed minimum temperature is less than 0°C.

As stated above, the daily frost series were converted into weekly frost series and the first order conditional probability transition matrices were investigated in the similar way as was done in rainfall analysis. A typical matrix from the chain is shown in Table 3.

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TABLE 2. A conditional probability transition matrix

	Period t								
	1	2	3	4	5	6	7	8	9
1	0.0– 0.46	0.47– 0.58	0.59– 0.77	0.78– 0.85	0.86– 0.88	0.89– 0.92	0.93– 0.96	0.97– 1.00	–
2	0.0– 0.50	0.51– 0.67	0.68– 1.00	–		–	–	–	–
3	0.0– 0.33	0.33	0.33	0.33	0.34– 0.67	0.68– 1.00	–	–	–
4	0.0– 0.67	0.67 0.67	0.68– 0.89	0.90– 1.00	– –	– –	– –	– –	–
5	0.0– 0.67	0.67	0.67	0.68– 1.00	–	–	–	–	–
6	0.0	0.0	0.0 1.00	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0 0.67	0.67	0.67	0.67	0.67	0.67	0.68 1.00	–	–
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 3. A conditional probability transition matrix for frost, for week 15 to week 16

1	0.00 0.91	0.92– 0.93	0.94– 0.97	0.98– 1.00
2	0.00 1.00	–	–	–
3	0.00 0.50	0.51 1.00	–	–

Evaluation of Climatological Models

Clearly, the predicted values of given climatological elements will frequently differ to some degree from the actual observed values. The reliability of forecast and the basic requirements for a method of estimating this reliability are important. Such method should be objective; it should permit a comparison of accuracy of forecasts of various climatological phenomena. That requirement can be satisfied if the estimate of reliability is based on statistical methods. The basic statistical measures are mean, standard deviation, skewness coefficient and correlation coefficient.

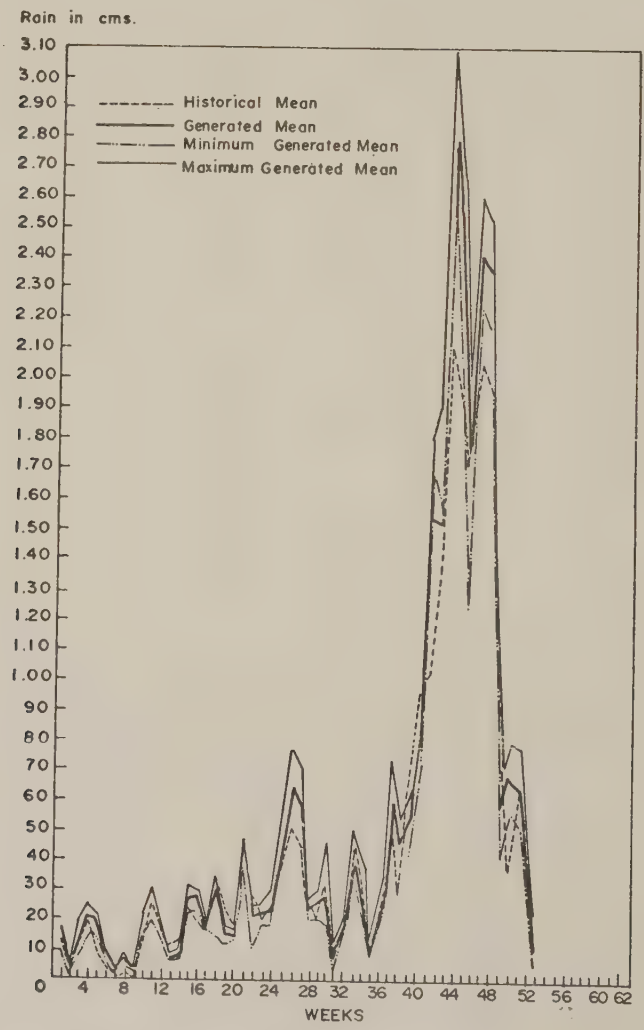

FIGURE 2. Comparison of historical and generated mean.

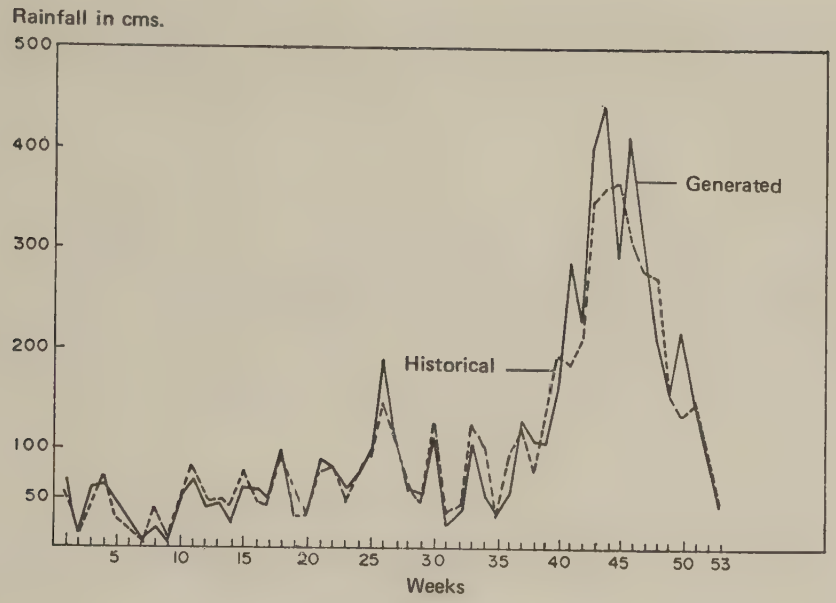

FIGURE 3. Comparison of standard deviation of rainfall

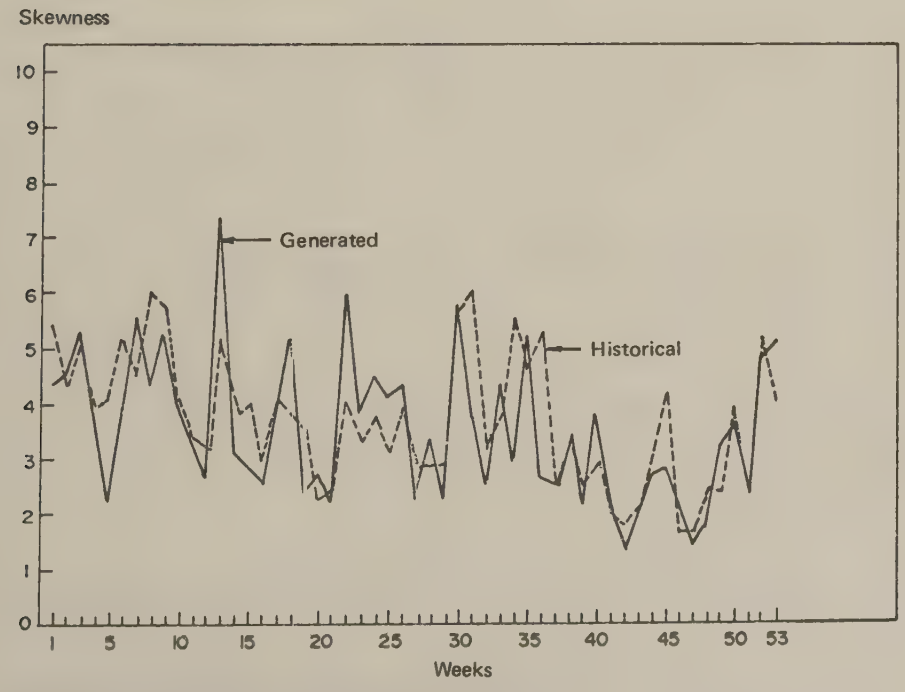

FIGURE 4. Comparison of skewness for rainfall

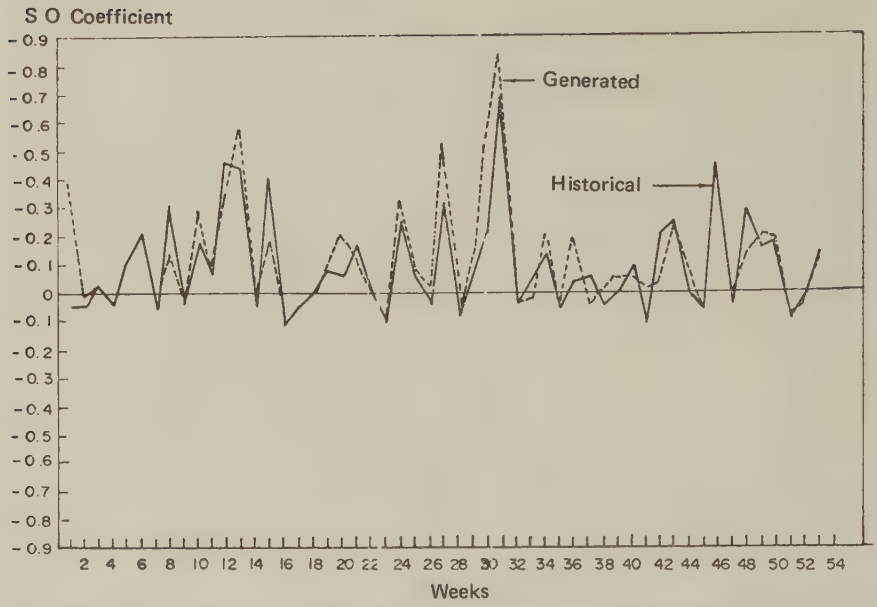

FIGURE 5. Comparison of serial correlation coefficient for rainfall

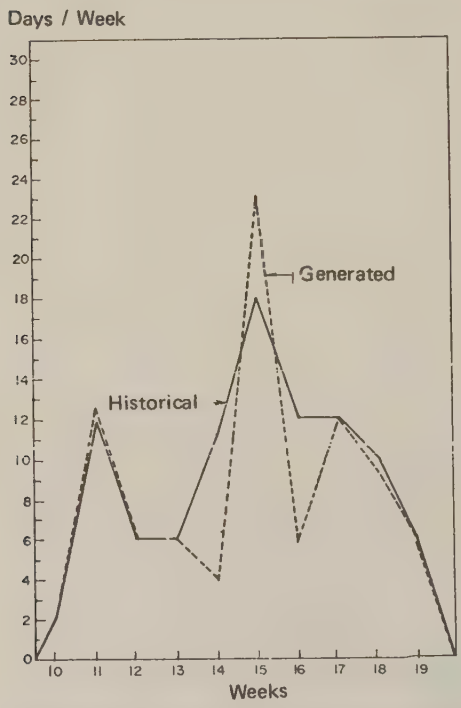

FIGURE 6. Comparison of mean for frost

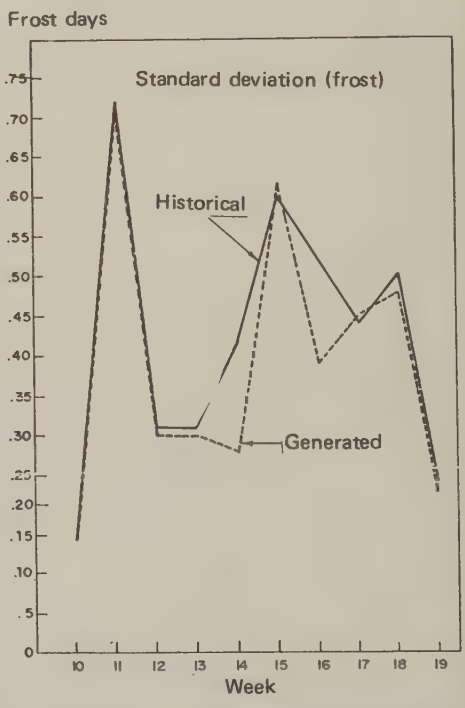

FIGURE 7. Comparison of standard deviation of frost

For the purpose of comparison, the parameters from the historical record and randomly generated records were plotted on the graph. The average value of 28 sets of weekly generated data of rainfall and frost of the same equivalent length as the historical record were used on plotting.

Evaluation of Rainfall Model

Fig. 2 shows the comparison of the average weekly rainfall. It shows a good agreement between the generated and historical data. It was observed that the variation between the historical and general values increases with an increase in the magnitude of rainfall amount. During the wet period, the difference is as high as 17%. Since the model was constructed on a weekly basis, accuracy higher than this cannot be expected. The model on the whole reproduced this characteristic satisfactorily.

The comparison of standard deviation (Fig. 3) indicates that model preserved this property satisfactorily. The maximum difference is observed during the wet period.

The comparison of skewness is shown in Fig. 4. Although the model was not constructed to preserve these characteristics, it holds this property quite satisfactorily.

Fig. 5 shows comparison of lag-one serial correlation coefficient. It is clear that lag-one serial correlation coefficients which were significant in the historical data are in good agreement with the coefficients produced by the generated data.

Evaluation of Frost Model

The comparison of historical mean frost days per week and generated mean frost days per week shows a good agreement (Fig. 6). The frost model to some extent over estimates at the peak period. It has significant agreement at earlier and latter periods.

Fig. 7 shows the comparison of standard deviation. The model reproduces desired characteristics satisfactorily. The model was not constructed to preserve the skewness.

SUMMARY AND CONCLUSIONS

Rainfall Model

Lag-one model correlation for weekly rainfall is 0.52. The model is also able to reproduce the standard deviation satisfactorily. Lag-one Markov chain did pre-

serve the skewness. The comparison of serial correlation coefficient shows that they are dependent. Historical means plotted with generated means showed good agreement.

Frost Model

Lag-one Markov chain model can be used satisfactorily for frost data generation, as the mean and standard deviation are in good agreement. However lag-one Markov chain model did not preserve skewness.

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MODELO DE LLUVIA Y ESCARCHA PARA LA SINCRONIZACION DEL SISTEMA DEL AZUCAR EN PAKISTAN*

M. K. Ayub y A. C. Early**

RESUMEN

Modelos metereologicas de lluvia y de escarcha son requeridas para sincronizar la politica de operaciones para cosechar la cosecha. Para cantidades de lluvia, la serie "lag-one" de correlacion de coeficiente semanal era 0.52, significante al 99% de probabilidad; entonces, un modelo "lag-one" de cadena Markov con el principio de tecnica de Monte Carlo fué usado para la generación de datos de lluvia. Los datos de lluvia generados con la técnica cuando e compararon con los datos historicos indicaron conformidad en el promedio, desviación uniforme, y coeficiente oblécuo (skewness coefficient). Aunque el modelo no fué dessarolado para el sesgo (skewness). La serie de "lag-one" de correlación de coeficiente computado de datos generados, congeniaban bien con los computados de datos historicos. Con respecto a la escarcha, la correlación de coeficiente no fué computada. Debido al procedimiento de calor en almacenaje de la atmosfera se tuvo como supuesto que el dato de escarcha tambien puede generar con un "lag-one" de cadena Markov. El dato generado con esta tecnica, cuando se comparó con los datos historicas, indico consistencia de promedio y de desviacion uniforme, aunque no prevervó el coeficiente de oblicualidad o de sesgo (skewness). Este estudio indica que la cadena Markov se puede usar eficazmente para la generación de datos de lluvia y de escarcha, ambos elementos teniendo particular importancia en el rendimiento de caña dulce en distritos irrigados de Pakistan.

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REVIEW OF CANE HARVESTER PERFORMANCE

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ABSTRACT

The paper discusses the evaluation of the harvesting process with particular emphasis on chopper harvesters in the Australian industry. The need for criteria such as cane collection efficiency and extraneous matter removal efficiency to supplement information on absolute levels of extraneous matter and cane harvested are discussed. Results obtained in extensive trials during the last three years, by both Sugar Research Institute and the Bureau of Sugar Experiment Stations, of a range of chopper harvesters are summarized and performances compared. The need for a measure of the quality of billets is discussed and the method of measurement used in Australia is summarized. The paper also discusses the effect of various harvester operating parameters on billet quality.

INTRODUCTION

There is a worldwide trend towards mechanization of sugar cane harvesting because of increasing cost of and difficulties in obtaining manual labor. However, the sugar industry in general is so diverse in terms of economic status, growing and crop conditions and existing harvesting practice that the type of mechanization varies greatly. Australia lies at one end of this spectrum because of its almost complete mechanization of the cane harvest using billet (or chopper) harvesters. (As of the 1979 season, absolutely no whole stalk or hand cut cane was delivered to a Queensland sugar mill.) Australia's view of cane harvesting problems are therefore very different from those of most other countries. The authors are therefore unable to discuss in any detail the procedures used outside Australia. The paper treats the topic in rather more general terms, considering the general requirements of any harvesting system. This will then indicate what measurements should be made to enable the mechanical performance of any harvesting system to be evaluated so that its performance can be compared with that of any other harvesting system. This discussion will be illustrated with data from recent harvesting trials using billet harvesters. However, the discussion will be limited to the changes that the harvesting process makes to the sugar cane between the cane standing in the field and that delivered to the sugar factory. No consideration will be given to cane cutting costs or to in-field utilization factors such as the amount of non-productive time associated with a particular harvesting system.

THE EVALUATION OF THE HARVESTING PROCESS

The harvesting process operates on the cane plant in the field (and to a limit-

ed extent on the top layer of dirt in the field) to produce an output which is convenient to consider in three categories:

(1) material (largely cane stalk) which is sent to the sugar factory;

(2) extraneous matter separated from the cane, and

(3) sugar cane and juices lost in the harvesting process.

This process is illustrated in Fig. 1. Methods of evaluating that process to produce some type of efficiency rating are discussed. The intention is that these ratings should be applicable to any type of harvesting system from completely manual cutting and loading, via manual cutting with mechanical loading through to completely mechanical harvesting. If suitable efficiency rating methods can be found, then the way is potentially open for direct comparison of the purely mechanical performance of different harvesting systems, although in practice the variability inherent due to differences in cane characteristics between different crops will always complicate the comparison.

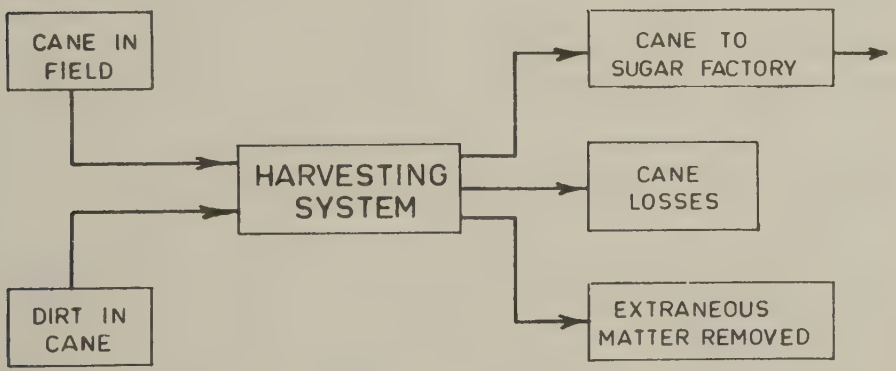


FIGURE 1. The cane harvesting process

Any harvesting system has two major functions: the collection of cane stalk and the rejection or removal of all unwanted material (e.g. leaves, tops, suckers, dead cane and dirt). In addition, one other characteristic must be quantified for a complete descripton of the system and that is the physical characteristics of the cane as it leaves the harvesting system and is delivered to the mill. The means of quantifying these three items are examined below.

CANE COLLECTION EFFICIENCY

The efficiency with which a harvesting system collects the sugar bearing cane material from the field can be measured by evaluating a cane collection efficiency (CCE). This is defined as the proportion of the cane stalk available in the field that is actually delivered to the sugar factory. In practice it could be determined as:

$$\text{CCE} = \frac{\text{Amount of cane originally in the field} - \text{amount left behind in the field}}{\text{Amount of cane originally in the field}}$$

This efficiency value has been termed the "harvesting efficiency" by Clayton *et al*[5,6]. However, the use of that phrase is avoided here partly because "efficient harvesting" implies more than just efficient collection of available cane, but also because other workers (Durante[10], Hodson[17], Gentil[14]) have used the phrase in association with entirely different aspects of the harvesting process.

An alternative way of expressing the cane collection efficiency is to determine the proportion of cane left behind in the field or otherwise lost during the harvest. Exactly the same data is required to evaluate both quantities and one can be readily calculated from the other by noting that the sum of the cane collection efficiency and the percentage of cane left in the field must equal 100%.

The determination of these efficiency values is not easy. The measurement of the net amount of cane delivered to the factory requires not only the weighing of the gross cane supply (which is generally routine) but also the determination of the amount of extraneous matter in that cane supply (which is awkward and potentially labor intensive). In addition all these readings must be related back to a specific area of cane field so that crop density values can be determined. This measurement of extraneous matter levels requires the sorting of a sizable proportion of the cane supply to try to obtain a value for the average level of extraneous matter. The means of obtaining that sample for sorting must be carefully examined to ensure that it is truly representative. Note that the actual amount of extraneous matter in the cane supply has no bearing on the cane collection efficiency as defined above. An efficiency of 100% would be obtained if all the cane in the field was delivered to the mill no matter how much extraneous matter was with the cane.

The remaining quantity required for the efficiency calculation is the amount of cane originally available in the field. The best approach to this is probably to determine as accurately as possible the amount of cane left behind in the field after the harvest and add this to the net amount of cane delivered to the factory. As subsequent discussion will show, this approach is fraught with problems when mechanical harvesters are in use because of the uncertainties associated with the loss of juice during the cutting process.

In recent Queensland investigations (Foster *et al*[11], Mason *et al*[19], Henkel *et al*[15], Fuelling *et al*[13]), the difficulties involved in taking the sample for extraneous matter level determination were overcome by taking a sample from directly under the delivery elevator of the harvesters while the harvester was operating at a steady speed. This ensured that all the dirt was collected and that there was no bias in favor of long or short billets as can exist in grab sampling methods. In this manner, in the trials undertaken by the present authors, samples constituting between about 2 and 4% of the 15 to 25 tons of cane harvested in each test were sampled for the determination of extraneous matter levels.

The cane losses within the field were evaluated by collecting all identifiable pieces of cane stalk that fell into a predetermined area while the cane was being harvested. The losses picked up in this small area were assumed to be typical of the whole test area. This collection proved to be a tedious labor intensive procedure partly because there was quite often a considerable amount of finely broken cane stalk (coming, it is thought from both base cutters and extractor fans). In extreme

cases, these fractured billets constituted a very significant loss.

The data collected in this manner were used to determine cane collection efficiencies for all tests conducted by the authors. The resulting values are displayed in Table 1. The tests involved several cane varieties in three different areas of Queensland and used Claas Libertadora 1400, Massey Ferguson 201 and 205, and Toft 4000 and 6000 harvesters. The data in Table 1 are only from those tests performed under reasonable harvesting conditions and indicate that average cane loss lies in the range 3-6%. Under damp weather conditions in certain varieties of green cane or when the harvester cleaning system was poorly tuned, efficiencies well below 90% were measured (the lowest being 81%).

TABLE 1. Cane collection efficiency values from recent Queensland tests with billet harvesters

	Cane Collection Efficiency (%)			Number of Harvesting Tests
	Minimum	Average	Maximum	
Burnt Cane	90.6	96.35	99.1	81
Green Cane	90.8	94.34	98.6	47

Differences between the characteristics of the canes in the individual tests make it difficult to directly compare different makes of harvesters. The data obtained by Foster *et al*[11] and Mason *et al*[19], suggests that in burnt cane the Claas harvester appears to leave more cane behind than the Toft or Massey-Ferguson harvesters, which leave approximately about the same amount. The difference cannot be quantified precisely but was generally less than a two-to-one ratio. They found the collection efficiency of the Claas harvester to be largely unaffected by the change from burnt to green cane. By contrast, the performance of both the Massey-Ferguson 205 and Toft harvesters deteriorated in changing from burnt to green cane. (The MF201 was not used in green cane.) For the Toft harvesters, the increase in cane loss was found to be quite small (less than a 50% increase) whereas for the MF205 the increased cane loss was more marked (somewhere of the order of a 200 per cent increase), which resulted in losses greater than those of the Claas harvester.

It is of interest to compare the efficiency data taken under Australian conditions with those measured in other countries. Presumably where cane is both cut and loaded completely manually, the cane collection efficiency must be very close to 100% although no data on this point has been found in the literature. However, data are available on other harvesting systems and these are shown in Table 2. The range of efficiencies shown here is very similar to those measured in Australia (Table 1), i.e. 90-99%. This indicates that as soon as any type of mechanization whatsoever is introduced into the harvesting process (i.e. either mechanical loading of hand cut cane or complete mechanical harvesting), then the cane collection efficiencies tend to drop significantly below 100% and that under adverse conditions can be as low as 80%. However, both Cruz[7] (Mexico) and Lengendre[18] (Louisiana) indicate that cane collection efficiencies might be expected to increase following

the introduction of chopper harvesters in place of hand cutting and mechanical loading because losses associated with mechanical grab loading can be very large.

The one doubtful aspect of this last statement concerns the extra losses associated with chopper harvesters due to loss of juice and fine cane particles at the base cutters and the chopper knives. These losses can easily be totally overlooked when assessing the amount of cane left behind in the field by chopper harvesters. No direct experimental evidence is available concerning these losses from within Australia although reports of major billet damage from extractor fans have been made (reference 1) and Mason *et al*[19] found losses in the form of finely smashed billets of up to 19% (i.e. cane collection efficiencies down to 81%) due to the passage of billets through extractor fans when harvesting a green cane with strongly adhering leaves. The presence of such smashed billets is indicative of the cane juice losses.

TABLE 2. Cane collection efficiency values from non-Australian sources

Type of Harvesting Operation	Country	Reference No.	AV. Cane Collection Efficiency Values (%)	Comments
Hand cut cane; mechanical loading	South Africa	12	94.0 to 98.3	Fields gleaned but loading losses may be omitted
	South Africa	13	97.9	Fields gleaned, 1% loading losses omitted
	Louisiana	14	92.5	Includes major mechanical loading losses
Whole stick mechanical harvesting; mechanical loading	South Africa	12	97.7	Loading losses may be omitted
	South Africa	13	94.3	No gleaning; 1% loading losses omitted
	Louisiana	4	80.2	
Chopper harvesters (gathering type as in Australia)	South Africa	12	95.3 to 97.3	
	South Africa	13	97.3	Toft 6000
	Louisiana	1	93.8 to 98.4	Low Efficiency in recumbent cane
	Louisiana	2	89.5 to 98.4	Toft 300, MF201. Low efficiency in recumbent cane
	Louisiana	4	88.6	MF201
	Louisiana	14	99.1	MF201

In the U.S.A., Clayton *et al*[4] specifically investigated damage and losses from base cutters and chopper knives using small scale experimental procedures. They fed cane into a chopper harvester and were unable to recover about 2%of the original cane (by weight) and reported that between 10-20% was otherwise lost in passage through the machine and was not recovered from the delivery conveyor.

Evidence for such losses under actual harvesting conditions can only be obtained by a direct comparison of manual and chopper harvested cane. In South Africa, de Beer *et al*[8,9] have conducted such experiments. His data on this point are not completely consistent. Four of his five trials show less cane harvested per hectare (even when field losses are allowed for) from chopper harvesters than hand cut cane. The reductions were 9.8%, 5.2%, 4.3% and 4.0% of which the first and third of these figures were statistically significant. The fifth test gave an increase of 6.5% (which was not statistically significant). Some data are also available from Rozeff and Tucker[20] in Louisiana. They show a slight (1.1%) increase in total cane per hectare (i.e. including field losses) for cane from a chopper harvester compared to manual harvest and grab loading, although the field losses were over four times greater in the grab loading than from the chopper harvester.

Examined collectively, the data on "juice" losses from chopper harvesters is not completely conclusive. However, there is enough evidence of potential internal losses within chopper harvesters to indicate that care is required when examining their cane collection performance.

EXTRANEOUS MATTER REMOVAL EFFICIENCY

When the performance of harvesters is investigated, the results generally contain statements about the percentage of extraneous matter in the harvested cane. This value is extremely important to the miller since it roughly describes the processing characteristics of the cane. However, it is obvious that this is not a wholly adequate statement because it makes no reference to the amount of unwanted material originally present in the field. It is therefore suggested that the method of measuring the ability of a harvester to remove the unwanted material (i.e. extraneous matter or EM) from the cane is to determine an extraneous matter removal efficiency (EMRE) which is to be given in conjunction with a statement concerning the percentage of EM contained within the harvested cane. In its simplest form this efficiency is the proportion of the extraneous matter present in the field that is removed or separated from the cane during harvest. In other words:

$$\text{EMRE} = \frac{\text{EM levels in the field} - \text{EM levels in the harvested cane}}{\text{EM levels in the field}}$$

A similar efficiency factor can also be calculated for the major components of extraneous matter (i.e. tops and leaves) but again should be stated in conjunction with the percentage of each in the cane. When the total extraneous matter removal efficiency is being determined, the way in which the dirt content is handled must be carefully considered. The dirt present in the harvested cane is obviously extraneous matter but it is impossible to meaningfully quantify the amount of dirt ini-

tially present in the field. It is suggested therefore that the dirt present in the field be ignored in any such efficiency calculation and that the efficiency of the harvesting system in preventing the inclusion of dirt in the harvested cane be indicated by a simple statement of the percentage of dirt in the harvested cane. In this case the extraneous matter removal efficiency would apply only to extraneous matter originating from the cane plant itself.

It is relevant to add at this point that the precise measurement of the dirt content of cane is quite difficult. Brotherton[2] and Henkel *et al*[16] have shown that the amount of loose dirt in a billet cane sample (i.e. dirt that can be shaken loose from the cane and other extraneous matter) is generally much less than half the amount that can be obtained by washing the dirt off the cane sample.

The difficult aspect of the removal efficiency is the determination of the extraneous matter levels present in the field prior to harvest. The only way to obtain this information is to sample the cane in the field and unfortunately this is rarely done. Clayton and Churchill[3] reportedly indicate that the "total trash content of a field of CP 41-223 sugar cane in Florida ranged from 30.4% to 19.9% as the crop season progressed from fall to spring" and that "preharvest burning reduced the total trash content by eight to ten %." Mason *et al*[19] found extraneous matter levels in the field ranging from 15-28% in green cane and from 3-21% in burnt cane. These figures give an indication of the potential problem involved in harvester design to reduce extraneous matter levels in the harvested cane.

The only data available to the authors that enable removal efficiencies to be calculated are from their own harvester trials. These values are shown in Table 3. Unfortunately, the sampling of the extraneous matter levels in the field prior to harvest received only a low priority in an otherwise crowded test schedule. Hence, the precision of these pre-harvest extraneous matter figures is poor. One indication of this is the negative efficiency for leaf removal in burnt cane. The cause is undoubtedly poor sampling of the cane in the field resulting in artificially low preharvest leaf levels.

However, although the precision of the data may be lower than ideal, Table 3 illustrates several points:

(1) The removal efficiencies are not in general very high.

(2) The efficiencies are higher in green cane when there is relatively more extraneous matter to be removed than in burnt cane.

(3) The removal efficiency for tops is higher in green than burnt cane. The reason for this is the increased sprawl caused by the burn which makes the topping mechanism less efficient.

(4) The efficiencies appear to vary with the initial amount of extraneous matter present in the field. To allow for this, the actual extraneous matter levels should be given for both before and after harvest as well as the removal efficiencies.

It is also instructive to examine the extraneous matter data for each of the individual tests in the two sets of harvester trials used to provide the data for Table

3. This information is shown in Fig. 2, 3 and 4 which give the variation in the level of total extraneous matter, leaf material alone and tops (and suckers) alone as harvester pour rate was varied. (The pour rate is defined as the rate at which the billet cane was delivered to the cane bin.) The highest pour rates in both burnt and green cane in each trial were obtained by asking the harvester operators to travel as fast as prevailing conditions allowed. The lower pour rates were obtained by slowing down the harvesters, using a crude speed indication system to enable constant ground speed to be maintained. In both trials, the weather was fine and dry, although in the October 1977 trial, conditions were exceptionally dry and the cane fires correspondingly fierce and thorough.

TABLE 3. Approximate extraneous matter removal efficiencies for chopper harvesters in Australia

Date of harvester trials		Oct 77	Nov 77	Oct 77	Nov 77
Cane condition		Burnt		Green	
Cane Variety		NCo310	Q90	NCo310	Q99
Average extraneous matter levels prior to harvest (%)	Leaves	0.1*	2.2*	7.3	8.6
	Tops	3.2	18.9	8.3	19.8
	TOTAL	3.3	21.1	15.6	28.4
Average extraneous matter levels in harvested cane (%)	Leaves	0.4	3.5	2.6	5.0
	Tops	1.4	11.4	0.7	6.4
	Loose Dirt	0.2	1.7	0.3	1.1
	Stones	0.3	—	—	—
	TOTAL	2.3	16.6	3.6	12.5
Extraneous matter removal efficiencies (%)	TOTAL	45	29	79	60
	Leaves	Negative*	Negative*	64	42
	Tops	56	40	92	68

**Result of poor sampling procedures*

In many respects, these two trials illustrate two extremes of cane harvesting in Queensland. This is partly due to the weather conditions as mentioned previously, but also because the cane varieties involved in the two trials were very different. Thus, the NCo 310 in the October trials were generally upright and had light, dry, spindly tops with very few green leaves. The Q90 and Q99 canes, on the other hand, had heavy juicy tops surrounded with reasonably lush green leaves. The cane fire was therefore much less effective in removing this leaf material. In addition, there was considerable sprawl in some of the crop, particularly the second ratoon burnt Q90.

Several aspects of the data in Fig. 2, 3 and 4 are of interest:

(1) The harvesting speeds in green cane are considerably less than those in

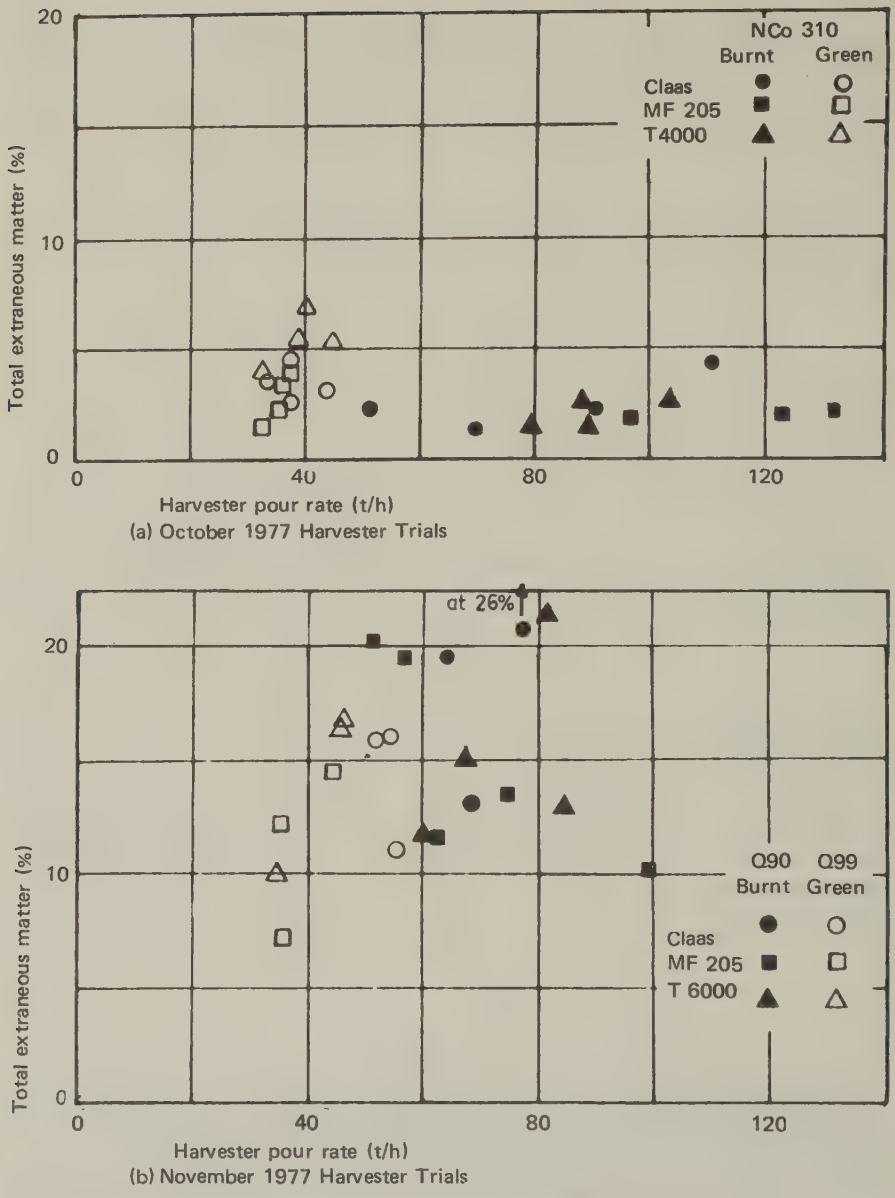
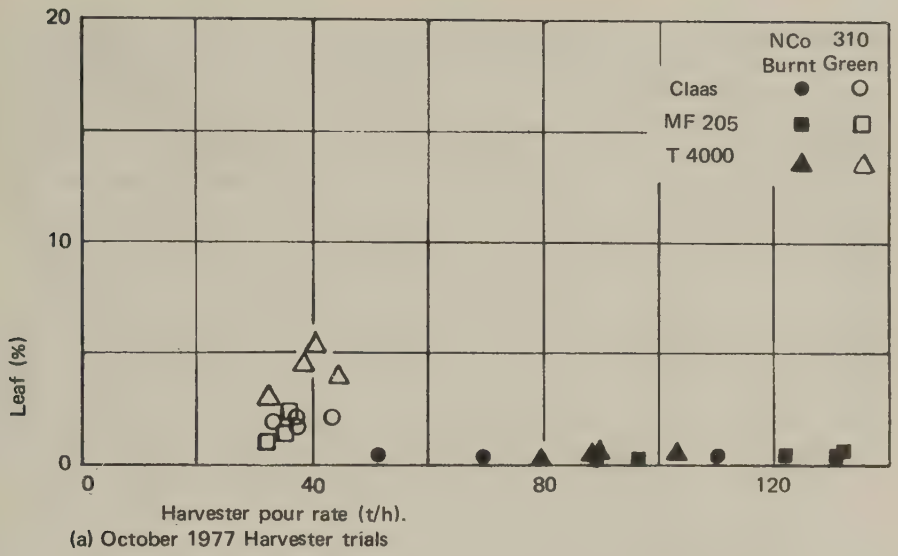
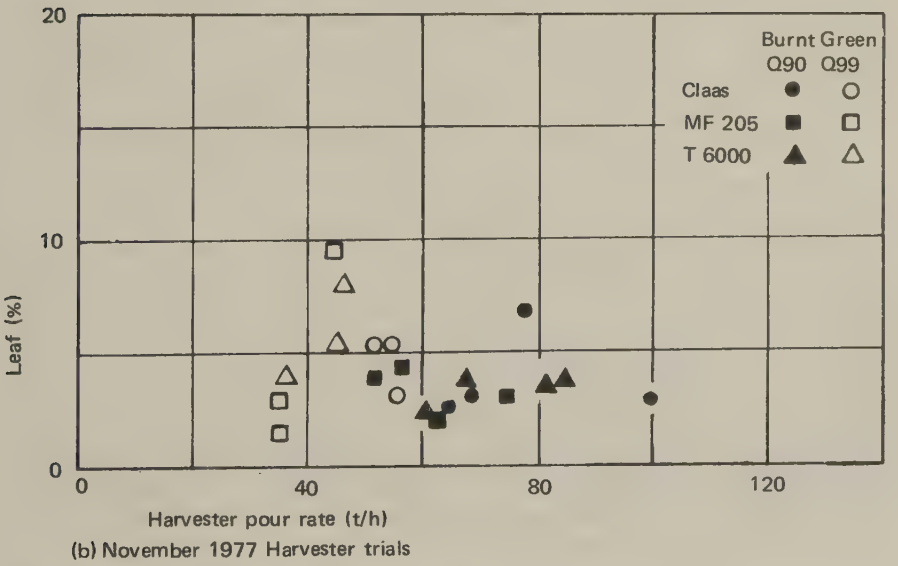


FIGURE 2. Variation in amount of total extraneous matter with harvester pour rate.

burnt. In the October trials, the maximum pour rate of each harvester in green cane varied between 28 and 43% of its pour rate in burnt cane. In the November trials, the relative pour rates varied between 55 and 59%, (although it must be stressed that the burnt cane was of a different variety to the green cane).



(a) October 1977 Harvester trials

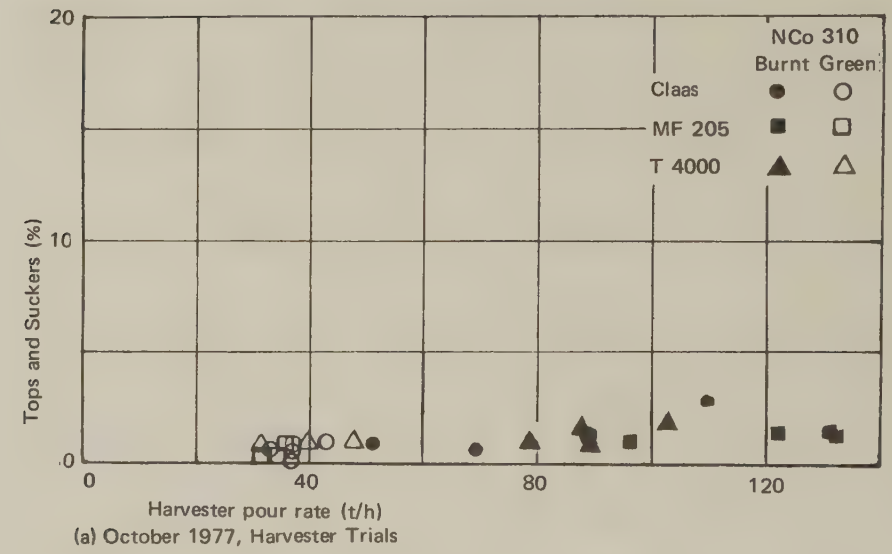


(b) November 1977 Harvester trials

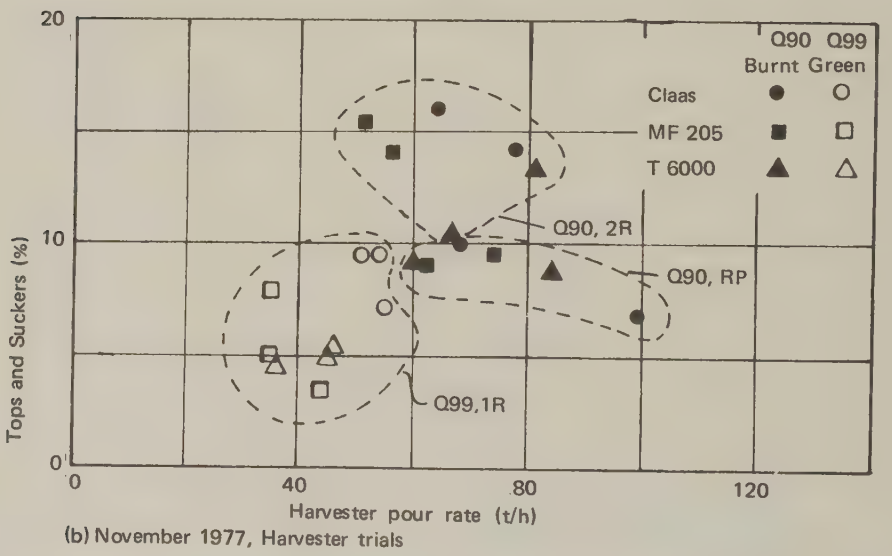
FIGURE 3. Variation in amount of leaf with harvest pour rate

(2) The higher total extraneous matter levels in the Q90, Q99 crop compared to the NCo 310 is due primarily to the tops content of the extraneous matter (although in the November trials, some suckers were also included with the tops).

(3) The effect of sprawl on the amount of tops in harvested cane is particularly well demonstrated by the results of the November trials (see Fig



(a) October 1977, Harvester Trials



(b) November 1977, Harvester trials

FIGURE 4. Variation in tops and suckers with harvester pour rate

4 (b). The crop had varying degrees of sprawl and the percentage of tops increased with the sprawl. The data for average amount of tops can be summarized as follows:

Upright, Green, First Ratoon Q99	6.4%
Bowed, Burnt, Replant Q90	8.8%
Sprawled, Burnt, Second Ratoon Q90	13.9%

The trial data also gave some indication on the effect of damp weather and harvester speed on extraneous matter levels. Damp weather affected two of the trials to a certain extent. In one, when harvesting green NCo 310, slight rain made the harvest effectively impractical because, although the harvester was able to process the crop, the leaf content levels rose to between 5 and 20% compared to less than 3% under dry conditions. This was partly due to the character of the NCo 310 cane variety (it has leaves that adhere strongly to the cane stalk) because under similar conditions, the same harvester could satisfactorily process green Q96. In another trial, the harvesting began just after dawn when there was considerable dew on the crop. As this dew evaporated, the leaf content of the harvested cane decreased. In green cane there was an average of 140% more leaf in cane harvested at 6:00 a.m. compared to midday. In burnt cane, the effect was less marked, with only 40% more leaf at 6:00 a.m. compared to midday. These results are such that their statistical significance cannot be determined although they were derived from a regression analysis on 12 data points for burnt cane, and nine for green cane.

CANE QUALITY

In addition to specifying the mechanical performance of a harvesting system in terms of its cane collection and extraneous matter removal efficiencies, it is necessary to measure the "quality" of the cane stalks or billets that are delivered to the sugar factory. This is necessary because deterioration of the post harvest cane depends on this "quality". Obviously, if the cane is whole stalk, a statement to that effect is basically adequate although additional comments about the quality of the base and topping cuts may be appropriate, particularly if they are machine cut.

However, the real need for a description of the cane quality arises when chopper harvesters are used. In this case, for a complete description it is necessary to specify average billet length, billet length distribution and the quality of the cuts at the ends of the billets. While the procedure to be used to measure the first two of these is reasonably obvious, the definition of a good or bad cut requires some thought. The criteria used by the authors was that a well cut end was one with a clean cut that was neither squashed (i.e. one from which juice could not be squeezed by finger pressure) not contained splits in the end of the billet more than 50 mm long extending across the diameter of the billet. More fundamentally, a well cut end is one that exposes a minimum area of cane stalk to the risk of infection either damaged (i.e. squashed or split end) but not so badly damaged as to expose a major portion of the core of the cane, in which case they were classed as mutilated ends.

Ideally, it should be possible to use these criteria to obtain the proportion of billet ends that were well cut, damaged and mutilated. However, in practice mutilation results in cane that is often not in the form of billets so that it is impossible to count the number of mutilated ends. An assessment of billet quality must therefore revert to a weight basis to give the proportion of cane by weight that falls into the following categories:

(1) Billets with both ends well cut

(2) Billets with one end well cut and one end damaged

TABLE 4. Billet quality data from recent Australian harvester trials

Harvester	Trial date	Cane variety	Burnt or green	Percentage of billets with well cut ends (Category 1)	Percentage of billets with at least one damaged end (Categories 2 & 3)	Percentage of mutilated cane (Category 4)	Av. length of well cut billets (mm)
Claas	Oct 77	NCo310	B	50	41	9	306
	"	"	G	75	18	7	274
	Nov.77	Q90	B	68	24	8	292
	"	Q99	G	74	18	8	296
MF205	Oct 77*	NCo310	B	72	19	9	231*
	"	"	G	77	16	9	207*
	Nov 77	Q90	B	79	15	6	247
	"	Q99	G	83	12	5	261
Toft 4000	Oct 77	NCo310	B	67	26	7	277
	"	"	G	70	19	11	303
Toft 6000	Nov 77	Q90	B	82	11	7	234
	"	Q99	G	78	13	9	273

** "Short Billet" kit fitted to this harvester*

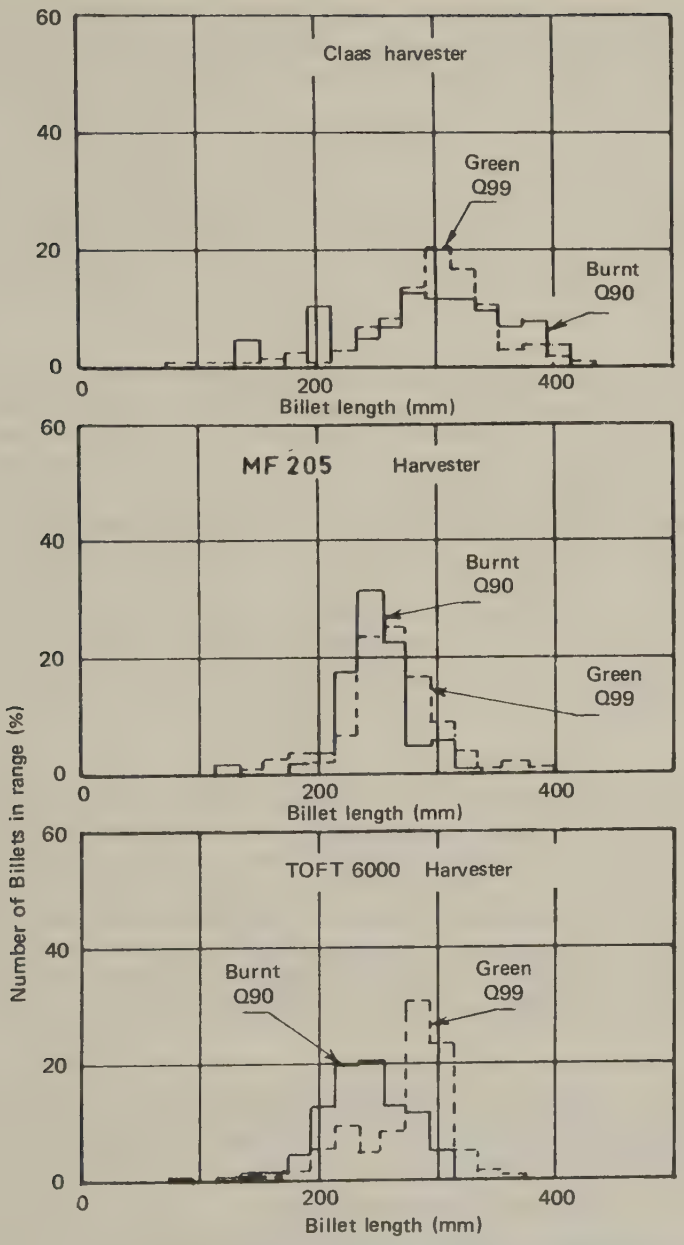


FIGURE 5. Billet length distribution obtained in the November 1977 trials

(3) Billets with both ends damaged

(4) Mutilated cane

While the authors now believe that the quality of the billet cut is best des-

cribed by dividing the cane with these four categories, in their trials categories (2) and (3) were combined. The results they obtained are shown in Table 4 which also gives the average billet lengths. Fig. 5 shows the distribution of billet lengths.

It should be possible to use billets in categories (1), (2) and (3) for the calculation of average length and length distribution although the authors only used billets with well cut ends (category [1]). Table 4 and Fig. 5 show nothing that is especially remarkable. They indicate that the Claas harvester used in these tests produced billets of longer average length and a greater length distribution than the other two harvesters, while the MF205 produced billet lengths with least variability.

The other fact that emerged during these trials was the importance of maintenance of the chopping mechanism to maintain both the quality of the cut and billet length. The Toft chopper knife required frequent replacement in order to maintain billet quality (although such changes can be made quite quickly) while the Massey Ferguson chopper blades seemed to require least attention, the most obvious example of such deterioration in quality occurred when the chopper blades on a Claas harvester were not sharpened for 22.5 hours of operation and the proportion of well cut billets during this time fell from 60% to about 12%. Some interesting work on blade sharpness was presented recently by Fuelling and Henkel[12]. Their results tend to confirm the above comments but also show that the Massey Ferguson chopper system tends to have a self-sharpening action.

CONCLUSIONS

The preceding paragraphs have discussed at some length the requirements for a complete description of the performance of a harvesting system in transferring the cane standing in the field to the form in which it is delivered. The major conclusion is that any such performance assessment must include some measurement of the cane and extraneous matter present in the field prior to harvest. Such assessments prior to harvest seem to have been totally ignored in most of the available reports on harvester trials. However, with such an assessment, a complete description of the harvesting process can be given in terms of:

(1) the cane collection efficiency,

(2) the extraneous matter removal efficiency and the removal efficiency for leaves and for cane tops alone, along with the actual percentage of each in the cane supply,

(3) the dirt content of the harvested cane,

(4) the average length and length distribution of the harvested cane (mainly applicable to billet cane harvesters), and

(5) the proportion of the harvested cane with well cut, damaged and mutilated ends.

The available data suggests that cane collection efficiencies can be quite high (up to 99%) although they can also fall quite dramatically (to as low as 80%) under

adverse conditions (e.g. damp weather, badly sprawled crop) and, for chopper harvesters, care must be taken to ensure that losses in the form of small cane chips or juice spray are not overlooked. Extraneous matter removal efficiencies on the other hand appear much less likely to reach efficiency levels above 90% in mechanical harvesting systems and can drop to very low levels. It would appear to be in this area that most improvement in mechanical harvester performance is desirable. The efficiency with which cane tops are removed is very dependent on the degree of sprawl in the cane. In upright cane efficiencies in the region of 90% appear possible although this quickly drops off as sprawl increases. In this regard, the pre-harvest burn of the cane is undesirable because it increases sprawl.

Th leaf removal efficiency appears to be generally lowest of all and the improvement of this efficiency appears to be the most urgent task facing mechanical harvester manufacturers. While cane tops are probably incapable of being separated from the cane once they have entered the harvester because of their similar physical characteristics to the cane stalk itself, they will tend to bring some sugar to the factory along with the other undesirable juices. Leaves on the other hand should be capable of separation from the cane within a harvester if the separator system is adequately designed. They almost certainly supply only unwanted juices to the sugar factory and carry more sugar out of the milling train than they bring in.

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REPASO DE LA EJICUCION DE LA COSECHADORA DE CAÑA

V. Mason, J. R. Allen, D. H. Foster y R. N. Cullen

RESUMEN

El papel examina la evalución del proseso de cosechar con ẽnfasis particular en cosechadoras "chopper" en la industria Australina. Se discuten la necesidad de un criterio o base como la eficiente colección de caña y de la eficiencia de la remoción de materias extraneas para suplimentar información en niveles absolutos de materia extránea y de caña cosechada. Se hace un sumrio y se compara la ejecución de resultados obtenidos en probaduras extensas durante los ultimos tres años, por el Instituto de Investigación Cientifica de Azúcar asi como la Oficina de Staciones de Experimento de Azúcar, de cosechadoras "chopper" de campo. Se discute la necesidad de tener una medida de la calidad de la boleta – "billet" y tambien se hace un compendio del método de medir usado en Australia. El tambien trata del efecto de varias cosechadoras de parametros operables en la calidad de la boleta (billet).

INDUSTRIAL QUALITY OF MECHANICALLY AND MANUALLY HARVESTED SUGARCANE

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ABSTRACT

The present work aimed at checking the quality of the raw material supplied to the industry using 2 chopper harvesters, (MF – 201 and SANTAL – 116) and manual harvest with mechanical loading.

To do so, a different methodology from the one regularly used was applied. The main parameter was ton pol/ha placed at the sugarmill track for each studied treatment. The sugarcane losses in the field and impurities were evaluated in an indirect way.

The technological parameters included in this study were: cane pol, fiber % cane, juice % cane, reducing sugar % juice, purity, ton/ha of harvested sugarcane and ton pol/ha.

In general, the manual harvest presented the highest values of cane pol, purity, ton/ha of harvested sugarcane and ton pol/ha. The values of fiber % cane were higher for the chopper harvester MF – 201, than for manual harvesting of the variety CB41–76. There was no difference for the manual harvesting of the variety CB41 – 76 and also for the various harvest systems for the variety CB56 – 155. The reducing sugar % juice was lower for the manual harvest than for mechanical harvests for the variety CB41 – 76. For juice % cane, there were differences only between manual harvest and harvest with the FM–201 for the variety CB41–76. No difference was registered for the variety CB56 – 155. In the mechanical treatments there was no difference in behavior for the variety CB56–155, which was standing. For the variety CB41–76, which was slightly inclined, the treatment with MF–201 resulted in a better yield in ton pol/ha, than with SANTAL – 116.

INTRODUCTION

With the shortage of workers and the necessity of reducing production costs, the sugarcane agro-industry was compelled to introduce into Brazil the mechanical harvester.

However, although mechanical harvesters were a solution to the shortage of workers, they gave rise to a new problem. They altered the quality of raw material with effects on the various stages of industrialization.

Therefore, many studies were done mostly concentrating on the evaluation of losses of sugarcane in the field and the impurities of the sugarcane raw material transported to the industry.

In the present work, a different methodology from the usual one was tested, where the quality of raw material supplied to the industry was evaluated, ton pol/ha being the main parameter.

Cochran and Clayton[3] defined the trash according to its effects in the sugarcane industrialization, as any material contributing to the decrease of the production of the recoverable sugar and affecting the sugarmill performance, decreasing the purity of the mixed juice, increasing the energy consumption, reducing the extraction coefficients of the mills and increasing production costs.

Fors[6] classified the trash resulting from mechanical harvesting as vegetal and mineral. Vegetal were trash tops, leaves, roots and defibered pieces of sugarcane. The mineral trash were the loose soil or soil adhered to the roots, stones, sand and pieces of metal.

The amount of trash depended on the width of sugarcane rows, presence of transversal furrows and prevailing humidity.

Nichols[12] demonstrated that leaves introduced as trash, retained less sugar than normal bagasse. It did not, therefore cause high losses in the recovered sugar, but caused an increase in expenses for transportation and processing as extraneous matter.

Waddell and Price[14] stated that the loss caused by the straw in industrial process comes mainly from its high content of fiber, ashes and soluble impurity. Besides, its high volume caused difficulties in feeding the mills and would absorb juice during the milling process, thereby, increasing the losses of sugar in the bagasse.

Mayoral and Vargas[9] pointed out that the main trash components in the Puerto Rico sugarcane are the green or dry leaves, tops, soil, stones, and mild and immature sprouts from the base of the stool. The most important losses caused by this material to the production was the great wearing of the equipment, aside from the higher loss of sugar in the bagasse, in the filtercake and in the molasses.

Humbert and Paine[7] in studying the effects of sugarcane harvest in wet weather in Hawaii, concluded that with the rain the burning was not satisfactory and there was an increase in the trash taken to the sugarmills. With the presence of trash, there was an increase in fiber, leading to a smaller extraction and therefore,

a decrease in the milling capacity. Moreover, the soil adhering to the sugarcane wore out the sugarmill equipment.

These caused problems to the juice clarification, leading to the need of greater investments to enlarge the capacity of this stage. There was also a decrease in the juice purity, reducing the sucrose recovery and increasing the amount of material of low quality to be handled.

The vegetal and mineral material reduced the sugar quality and therefore increased the refining costs.

Dudley *et al*[4] in studying sugarcane harvest in Puerto Rico, stated that tops going to sugarmills together with the raw material introduced in the process non-crystallizable sugar. These reducing sugars decreased juice purity and increased losses in sucrose.

Morin[11], in studying mechanical harvest of sugarcane in Tucuman found the following figures for sugarcane juice quality:

	Purity %	Pol Cane	Production Yield	R.S.
Without trash	86.54	13.09	11.16	0.414
With trash	82.86	10.39	9.73	0.673

Elias[5], in studying the effects of mechanical harvest in the sugarcane industrial quality at the Regional Experiment Station of Cattle Breeding of Famillа, worked with four varieties: CP48-103, NA56-62, NA56-79 and NA63-90. The variety presenting the lowest impurity content was NA56-79, being followed by NA56-62, CP48-103 and NA63-90.

It should be emphasized that values achieved for NA56-79 were considered normal, since losing the straw at maturation was a characteristic of this variety. The values obtained showed that a large amount of impurity corresponded to a smaller juice extraction.

Ayala *et al*[2] in studying the influence of harvest types on sucrose loss in the factory obtained values showing that there was a considerable increase in the bagasse percentage in the mechanically harvested sugarcane. This increase was proportional to a bigger or smaller neatness in the mechanical harvest, i.e., it was directly related to trash. In the trials made, there were increases in the bagasse % cane for the mechanically harvested sugarcane.

Bagasse increase would result, among other consequences, in a decrease of the milling capacity and increase of mechanical wearing of the sugarmill equipment which could not easily be measured but were very important during the harvest.

Arceneaux and Davidson[1] in the U.S.A. found that for a 7.5% trash there was a reduction of 2.12% in the extraction. The purity of extracted juice decreased

to 2.17 degrees for each 10% of impurity. If impurities had green leaves, the purity reduction was 3.02 degrees for each 10% of trash.

MATERIALS AND METHODS

The following main equipment were used in the study:

1. MASSEY – FERGUSON CHOPPER HARVESTER (MF – 201) CANE-COMMANDER: with V8-510 PERKINS engine; maximum power from 142 hp 9106 (106 kw) at 2000 rpm, DOWMATE hydrostatic transmission.

2. SANTAL–116 CHOPPER HARVESTER: with MWM–6 engine and GARRET turbine, maximum power from 135 hp (101 kw) at 2300 rpm, with oil radiator and protector against straw in the turbine.

3. TOLEDO WEIGHING–MACHINE: with capacity for 56,000 kg. precision of 5 kg. model 2,890.

The work was carried out at Barra Sugarmill S/A Sugar and Alcohol, in Barra Bonita, State of Sao Paulo.

Two sugarcane varieties were used: CB56–155, 9th cut and CB41–76, 5th cut.

Field Conditions of Varieties

CB56–155

The plantation was at the 9th cut. The rows were in a superior level in relation to the inter-rows, therefore, cutting in the base was feasible.

The plantation was burnt at 6:00 p.m. on August 16 and the harvest took place on August 17, 1978 from 6:30 a.m. to 4:00 p.m.

Visual observation after burning showed an insignificant amount of green leaves.

CB41–76

The plants were slightly inclined towards the row at the 5tn cut, this area being duly cultivated to enable basal harvest of stalks by the machines conducting earth to the rows.

Through the cultivation and ratoon stage (5th cut) the sugarcane row was in a superior level if compared to the interrow.

The plantation was burnt at 5:30 a.m. on September 20, 1978 and the cutting period went till 5:30 p.m. In a visual appreciation of the area, some green leaves were observed.

The statistical delineation of the area was through the method of randomized blocks with 5 replications.

Treatments

The treatments were:

1. Harvest with MF–201 equipment,
2. Harvest with SANTAL–116 equipment and
3. Manual harvest with mechanical loading

For all treatments, the regular operating conditions of the sugarmill were followed:

The trials were characterized by the following:

1. Harvest of plots and transportation of sugarcane to the mill were by trucks.

2. Measurement of the plot areas and weighing of loads at the sugarmill scales to enable the calculation of ton/ha of the harvested sugarcane.

3. Unloading of sugarcane for sampling at the sugarmill yard for manually harvested cane and on the transportation track, for mechanically harvested cane.

4. Removal of 5 compound samples in each load for the technical analysis, totalling 25 samples per treatment.

For the technical analysis, the samples were passed through a shredding machine and the juice of a sub-sample of 500 g of shred material was taken through the hydraulic press PINETTE–EMIDECAU–CODISTIL at a pressure of 245 kgf/cm^2 applied for one minute.

With the extracted juice, the following were measured: the pol through Schmitz' method, Meade and Chen[10] without dilution; the reducing sugars, (Lane and Eynon[8]), and the refractometric brix.

The pol cane was calculated from the pol juice and the fiber % cane from the fibrous residues of the pressing according to PLANALSUCAR[13].

With the data achieved for ton/ha of harvested cane and pol cane, it was possible to calculate the harvested ton/pol/ha.

Juice purity, was calculated.

The juice % cane was calculated from the extract juice at hydraulic pressure of 245 kgf/cm^2 applied for one minute.

RESULTS AND DISCUSSION

The average of the harvest types in the various determinations accompanied

TABLE 1. Means and variation coefficients of technological determination for the variety CB41-76 manually and mechanically harvested

Determination	Manual	Santal–116	MF–201	C.V. %
Cane Pol	13.90 a	12.24 b	11.70 b	3.06
Fiber % Cane	11.59 a	12.15 a,b	12.80 b	3.00
Juice % Cane	71.12 a	68.93 a,b	68.46 b	1.97
Reducing Sugar % Juice	0.56 a	0.68 b	0.79 c	8.24
Purity	91.17 a	88.00 b	86.61 b	1.15
ton/ha	99.44 a	76.14 b	106.10 a	6.17
ton pol/ha	13.81 a	9.32 c	12.42 b	6.88

Means followed by different letters are statistically different. (Tukey – 5%).

TABLE 2. Means and variation coefficients of technological determinations for the variety CB56-155 manually and mechanically harvested

Determination	Manual	Santal-116	MF-201	C.V. %
Cane Pol	12.54 a	11.02 b	10.74 b	5.08
Fiber % Cane	12.03 a	12.13 a	12.25 a	2.03
Juice % Cane	67.87 a	66.87 a	66.75 a	1.35
Reducing Sugar % Juice	1.12 a	1.31 a,b	1.43 b	10.41
Purity	88.45 a	83.89 b	84.12 b	2.54
ton/ha	103.72 a	95.37 a,b	91.29 b	6.23
ton pol/ha	13.02 a	10.48 b	9.80 b	7.04

Means followed by different letters are statistically different (Tukey – 5%)

by the respective variation coefficient are shown on Tables 1 and 2 for the varieties CB41-76 and CB56-155.

Cane pol and purity

The cane pol analysis is of great importance since it is an important parameter for the judgment of the sugarcane sucrose content.

The purity consists of the percentage relationship between pol and juice brix, being one of the points mostly used in the appraisal of raw material quality.

For the two studied varieties, the manual harvest presented the higher cane pol and purity contents, being different from mechanical harvests, which presented the same amounts.

This variation was probably due to the best utilization of raw material by the manual harvest.

Fiber % Cane, Juice % Cane and Reducing Sugars % Juice

High fiber % cane content presented a negative effect on the milling capacity and on sucrose extraction.

The reducing sugars, as well as the pol cane, were of great importance as parameters to indicate the sucrose inversion among the treatments.

For the variety CB41-76, which was slightly lodged, the MF-201 harvested cane gave the highest fiber content and the lowest amount of juice % cane, compared to the manual harvest. Between the mechanical treatments, there was no difference. Concerning reducing sugar % juice, the MF-201 equipment gave the highest content, followed by the SANTAL-116, the smallest value being with the manual harvest.

This occurred probably due to the presence of a larger amount of tops in the material harvested by MF-201.

Concerning the behavior of the variety CB56—155 which was erect, there were differences only to reducing sugar % juice. The manual harvest had a lower content when compared to that of the MF—201 harvest which did not differ from the SANTAL—116.

Ton/ha of harvested cane

For the slightly inclined variety, the MF—201 equipment presented a behavior similar to the manual harvest, regarding the ton of harvested sugarcane, but was different from the SANTAL—116, which left more sugarcane in the fields.

For the standing variety (CB56—155) there was a similarity of behavior between the mechanical treatments and between manual and SANTAL—116.

Ton pol/ha

For the two varieties, the manual harvest presented the highest values of ton pol/ha being different from the mechanical harvests.

Between the mechanical harvests for the standing variety, the behavior concerning ton pol/ha was similar.

For the variety CB41—76 (slightly inclined), the MF—201 presented a higher value for ton pol/ha than the SANTAL—116.

CONCLUSIONS

The manual harvest provided under the experiment conditions, the best values for the technological parameters (pol cane, fiber % cane, juice % cane, reducing sugar % juice and purity), and, provided higher tonnage of harvested sugarcane and tonnage of sugar per hectare.

Between mechanical treatments there was no difference of behavior in the analyzed parameters for the variety CB56–155, which was erect.

Concerning the variety CB41–76, slightly inclined, the treatment with MF–201 equipment presented a better operational behavior.

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CALIDAD INDUSTRIAL DEL CORTE MECANIZADO Y CORTE MANUAL DE LA CAÑA DE AZUCAR

S.E. Ferrari, V.L. Furiant Nieto, J.J. Correa Lopes y R. Stolf

RESUMEN

Este trabajo esta encaminado a verificar la calidad del material suplido a la industria usando 2 cosechadoras combinadas (MF–201 y SANTAL–116) y corte manual con alce mecanico.

Para esto se uso una metodologia differente de la convencional, donde el parametro principal es ton pol/ha entregado en el molino para cada una de las pruebas, evaluando las perdidas de caña en el campo e impurezas.

De este modo los parametros tecnologicos incluidos en este estudio son: caña pol, % de fibra, % de jugo, % de azucar reductora en el jugo, pureza, ton/ha de caña cosechada y ton pol/ha.

Los valores encontrados fueron analizados estadisticamente y discutidos resultando las siguentes conclusiones:

– en general, el corte manual presenta los valores mas altos de pol en la caña, pureza, tons/ha de caña cosechada y ton pol/ha.

– el % de fibra en la caña fue mas alto para la cosechadora combinada MF–201 si la comparamos al corte manual, para la variedad CB41–76. No hubo diferencia para los distintos tipos de cosecha en la variedad CB56–155.

– en lo que concierne a % de azucares reductores en el jugo el corte manual presento los contenidos menores, en comparacion a la cosecha mecanica, para la variedad CB41–76.

– para % de jugo, hubieron diferencias unicamente entre la cosecha manual y la cosecha con la MF–201, para la variedad CB41–76. No se registro diferencia para la variedad CB56–155.

– en los tratamientos mecanicos no hubo diferencia en el comportamiento de la variedad CB56–155 la cual era erecta.

– para la variedad CB41–76, la cual era ligeramente inclinada, el tratamiento con la combinada MF–201 resulto en un mejor rendimiento en ton pol/ha que la SANTAL–116.

INVESTIGATION OF THE RELATIONSHIP AMONG QUALITY OF CHOPPED SUGARCANE VOLUMETRIC WEIGHT AND LOADING COEFFICIENT OF TRANSPORTATION

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ABSTRACT

This paper deals with the results of investigation of the volumetric weight of chopped sugarcane, the analysis of relationship between volumetric weight and contents of extraneous matter, the biological yield of sugarcane, length of billets and the loading coefficient of trailers.

Based on this analysis we came to the following conclusions: that weight of chopped vegetable mass volumetricness ranged from 300 to 330 kg/m^3, the trailer loading coefficient varied from 0.28 to 0.31 when yields of cane fields were from 106.6 to 157 mt/ha and the contents of extraneous matter ranged from 12% –28%.

INTRODUCTION

Mechanization of sugarcane harvesting is one of the main tasks of Cuba's complex mechanization problem of sugarcane production. Generally, during harvesting a great number of men day^6/ha is employed and this number is increased in the rainy season. The complete mechanization of such a laborious work is necessary because sugarcane must be harvested during a very short lapse of time in order to avoid losses in sucrose content, and at the same time prepare cane fields for cultivation of ratoons (Betancourt[1, 2, 3] and Gonzalez[4, 5]).

In order to reduce labor in the sugarcane production it is necessary to significantly increase the level and rate of mechanization of all of these works, mainly during harvesting season (Hurtade[6]).

The performance of this task depends to a great extent on crop quality, the stalks chopped by combine harvester, cleanliness of elaborated vegetable mass, its volumetric weight and the loading coefficient of transportation media. The coordinated work of combine-harvester with transportation media has also an influence, Peralta, Dominguez and Fonseca[8, 9]

The objective of the study is mainly to explain the influence of the extraneous matter content on the volumetric weight of vegetable mass chopped and on the loading coefficient of trailer.

MATERIALS AND METHODS

During the harvesting process performed by KPT-1 combine harvester, chopped stalks first went to the longitudinal conveyor and then to the discharge conveyor.

During their transport, chopped stalks were separated by means of a fan into heavy fractions (billets) and light fractions (trash and green leaves). Light fractions were expelled outside and heavy fractions were dropped into the trailer that went along the combine harvester.

On the other hand, a portion of the light fractions (extraneous matter) were also dropped into the trailer and had a negative influence on the volumetric weight of the vegetable mass and on the loading coefficient, while the length of chopped billets had a negative influence on the above factors.

Obtaining real numerical values of the contents of extraneous matter, volumetric weight of elaborated vegetable mass and the loading coefficient was therefore essential in order to determine optimum shapes and sizes of trailers.

In order to make a study on these, special field and laboratory trials were conducted.

Harvesting and chopping of sugarcane stalks were carried out by means of a KPT-1 sugarcane combine harvester for sugarcane variety Ja. 60-5. The time consumed for the loading operation up to the upper edge of a trailer was measured with a chronometer. Afterwards, all the vegetable mass contained in each trailer was weighed by means of a scale. To determine the productivity of the harvester, the harvested areas were measured simultaneously.

Experiments were conducted in the field with different biological yields. Usually, the volume of harvested vegetable mass is calculated by the formula:

$$\gamma = Q/sV$$

where: Q: weight of harvested vegetable mass, kg
v: volume of trailer, m^3
s: specific weight of clean cane, g/cm^3

Vegetable mass chopped during harvesting was made up of the following com-

ponents:

a — clean cane
b — trash and dry stalks
c — tops
e — suckers

These components had different moisture contents. To determine the total weight of harvested vegetable mass it was necessary to take into account the differences in moisture content of the different constituents.

The experiment had 10–20 replicates. Samples of each components were weighted separately and moisture samples were taken from each.

From clean cane, samples of 100 units were taken to measure length and diameter of stalks. The length of stalk pieces was measured from one end to the other by using a measuring tape, and the diameter was measured by means of a vernier caliper.

Obtained values by means of calculation were allowed to take the weight of components to a supposedly uniform moisture system. Afterwards, the % content of each component was finally calculated. These data were able to correlate some relationship between volumetric weight and extraneous matter content.

RESULTS

A. Changes in components of extraneous matter content depending on the biological yield of sugarcane. Results of this investigation are shown in Fig. 1.

The clean cane % content of harvested vegetable mass increased proportionally with biological yield of sugarcane, although to a certain extent (138.3 mt/ha) the increase is not significant. Thus, when biological yield of sugarcane ranged from 106.5 mt/ha to 138.3 mt/ha, the clean cane % content increased by 11.15% and when biological yield increased from 138.3 mt/ha up to 157.7 mt/ha there was a 4.47% increase.

Tops % content in harvested vegetable mass decreased with an increase in biological yield. Thus, with an increase in biological yield from 106.5 mt/ha to 138.3 mt/ha (Fig. 1 curve b), tops content decreased by 11.80%, and afterwards, with an increase in the biological yield up to 157.7 mt/ha. tops % content was almost constant.

Trash and dry stalk % content in harvested vegetable mass decreased with an increase in the biological yield of sugarcane. It should be pointed out that dec-

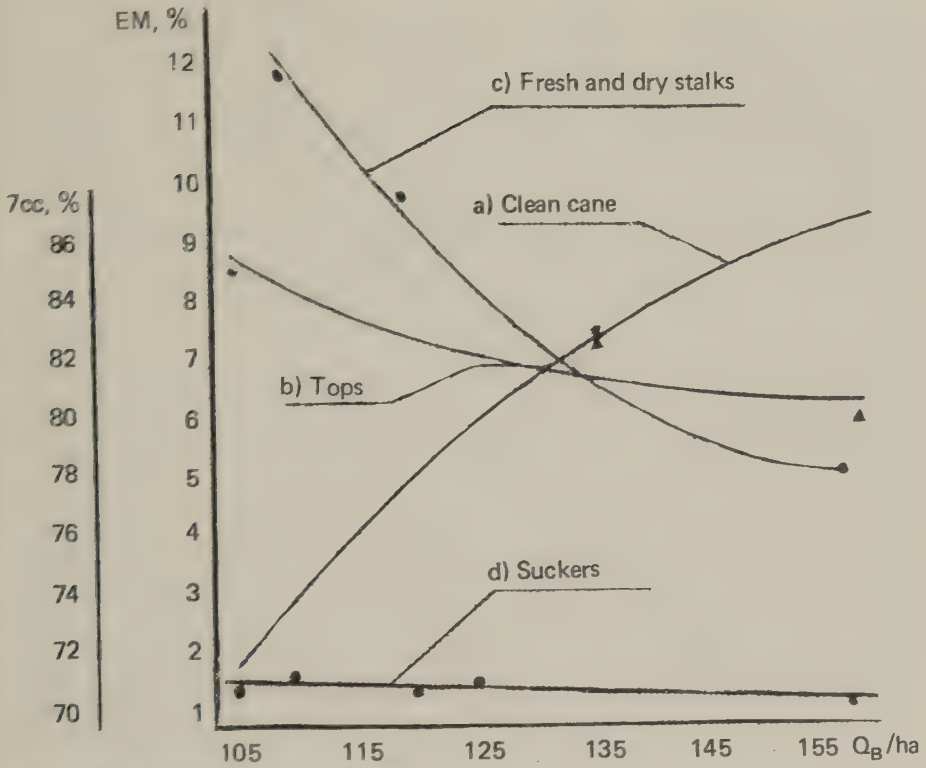

FIGURE 1. Variations in the weight of clean cane (% cc) and components of extraneous matter (EM) depending on the biological yield of sugarcane (Q_B).

rease in trash and dry stalks (Fig. 1, curve c) was significantly remarkable with sugarcane biological yields up to 138.3 mt/ha, having no influence in the trash and dry leaves content of harvested vegetable mass and later increase in yield. Thus, with an increase in biological yield from 106.5 to 138.3 mt/ha the dry leaves and dry stalks % content of harvested vegetable mass decreases 2.3 times, but with an increased biological yield of sugarcane from 138.3 to 157.7 mt/ha it decreased 1.2 times. This was due to the fact that the dry cleaning system of sugarcane harvested was not able to entirely separate extraneous matter from the harvested vegetable mass. In Fig. 1 (curve a) it is clearly seen that chopped clean cane % content of harvest vegetable mass did not increase significantly with an increase in the biological yield.

Suckers % content in the harvested vegetable mass did not change significantly with an increase in biological yield of sugarcane. Thus, with an increase of biological yield of sugarcane from 106.5 to 157.7 mt/ha Fig. 1 (curve d) suckers % content in the harvested vegetable mass only decreased 1.23 times. This phe-

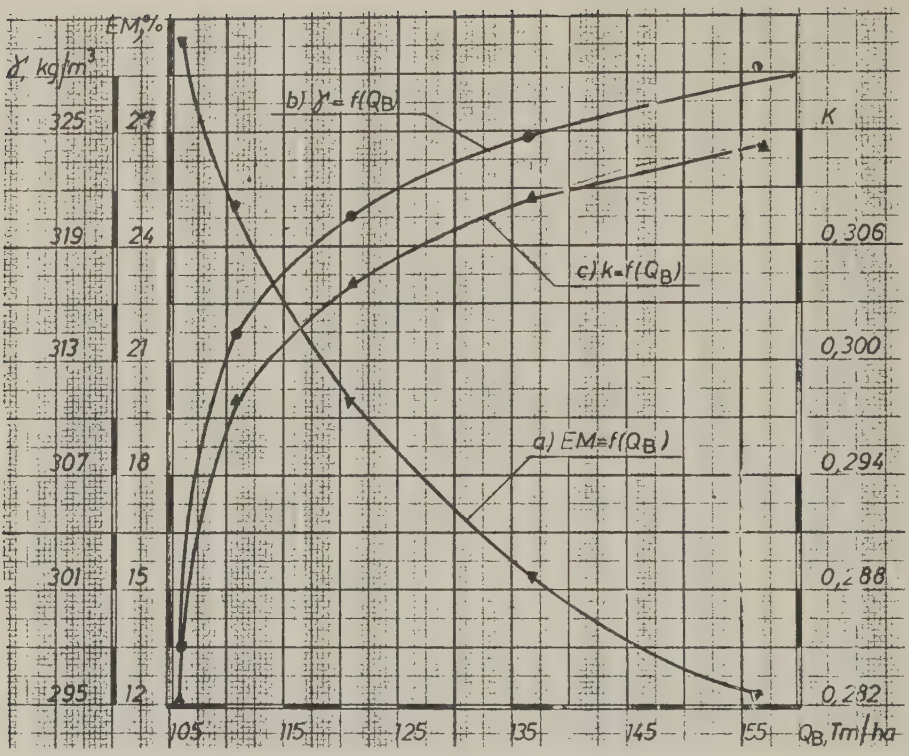

FIGURE 2. Variations in the volumetric weight of harvested vegetable mass (f) extraneous matter (EM) and loading coefficient of tracter (k) depending on the biological yield of sugarcane (Q_B).

nomenon could be explained by the fact that when sugarcane yields were high there were no proper conditions for the suckers to grow.

B. Changes in extraneous matter content, volumetric weight of harvested mass and loading coefficient of trailers depending on biological yield of sugarcane. Results of this investigation are shown in Fig. 2.

From Fig. 2 (curve a), with an increase in the biological yield of sugarcane, there was a decrease in the extraneous matter content (EM). At the beginning there was a significant decrease and later on it became not significant, because the increase in the sugarcane yield was due to an increase in the length and thickness of these stalks. In this case the number of tops remained the same.

The insignificant reduction of extraneous matter content in the trailer was due to a decrease in the amount of trash in the harvested vegetable mass which depended on the cleaning capacity of the harvester. Thus, with an increase in the biological yield of sugarcane from 106.5 to 138.3 mt/ha, the extraneous matter

% content decreases 1.8 times, but with an increase in yield from 138.3 mt/ha. 157.7 mt/ha there was a 1.26 decrease.

In Fig. 2 (curve b) it is also seen that with an increased biological yield of sugarcane, i.e. with an increase in the weight of harvested vegetable mass in the trailer, the volumetric weight of harvested vegetable mass increased significantly at the beginning and not significantly, afterwards. Thus, with an increase in biological yield from 106.6 to 121.6 mt/ha, the volumetric weight of elaborated vegetable mass increased by 8%, but with an increase in yield from 138.3 to 157.7 mt/ha, the volumetric weight of the elaborated vegetable mass increased by only 2.4%.

Changes in the loading coefficient of the trailer indicated the part of the total volume of the trailer was loaded with chopped clean cane. In order to determine the loading coefficient of the trailer, the following formula is used:

$$K = \frac{qm}{S\ V_t}$$

Where: K : loading coefficient of trailer
q_m: weight of harvested vegetable mass, kg
S : specific weight of clean cane, kg/m^3
V_t: volume of trailer, m^3

Specific weight of clean cane was experimentally determined as

$$S = 1055\ \text{kg/m}^3$$

Obtained data depending on biological yield of sugarcane is shown in Table 1.

TABLE 1. Values of main parameters depending on biological yields of sugarcane

No. of order	Biological yield of sugarcane MT/ha	Weight of harvested vegetable mass in trailer q_m kg	Weight of chopped clean cane in trailer q_{cc} kg	Extraneous matter in harvested vegetable mass EM, %	Volumetric weight of harvested vegetable mass in trailer kg/m^3	Loading coefficient of trailer with chopped clean cane K
1	157.7	4928.41	4328.15	12.18	328.55	0.311
2	138.3	4895.03	4191.98	14.24	326.34	0.309
3	138.3	4844.13	4045.82	16.48	322.94	0.308
4	121.6	4837.79	3975.70	17.82	322.52	0.306
5	121.6	4819.25	3874.68	19.60	321.28	0.305
6	121.6	4771.54	3693.18	22.60	318.10	0.302
7	111.1	4745.81	3590.21	24.35	316.39	0.300
8	111.1	4694.79	3476.96	25.94	312.99	0.294
9	106.5	4469.72	3203.90	28.32	297.98	0.282

Based on the data from Table 1, Fig. 3 was plotted. From curve c it is seen that with an increase in the weight of harvested vegetable mass and also with an increase in biological weight of sugarcane, the loading coefficient of the trailer with chopped clean cane (billets) increased. For example, if weight of harvested vegetable mass in trailer was 4,928 mt, the loading coefficient was 0.31, that is, 31% of the trailer's volume was filled with harvested chopped clean cane (billets) the remaining of the trailer's volume i.e. 69% was not used since it was filled with extraneous matter and empty spaces. When the weight of harvested vegetable mass in the trailer was 4,469 mt the loading coefficient was 0.28 that is, 28% of trailer's volume was filled with clean cane and the remainder of the trailer's volume was filled with extraneous matter and empty spaces.

C. Changes in the volumetric weight of harvested vegetable mass weight of clean cane and increase in transportation media depend on the content of extraneous matter in harvested vegetable mass.

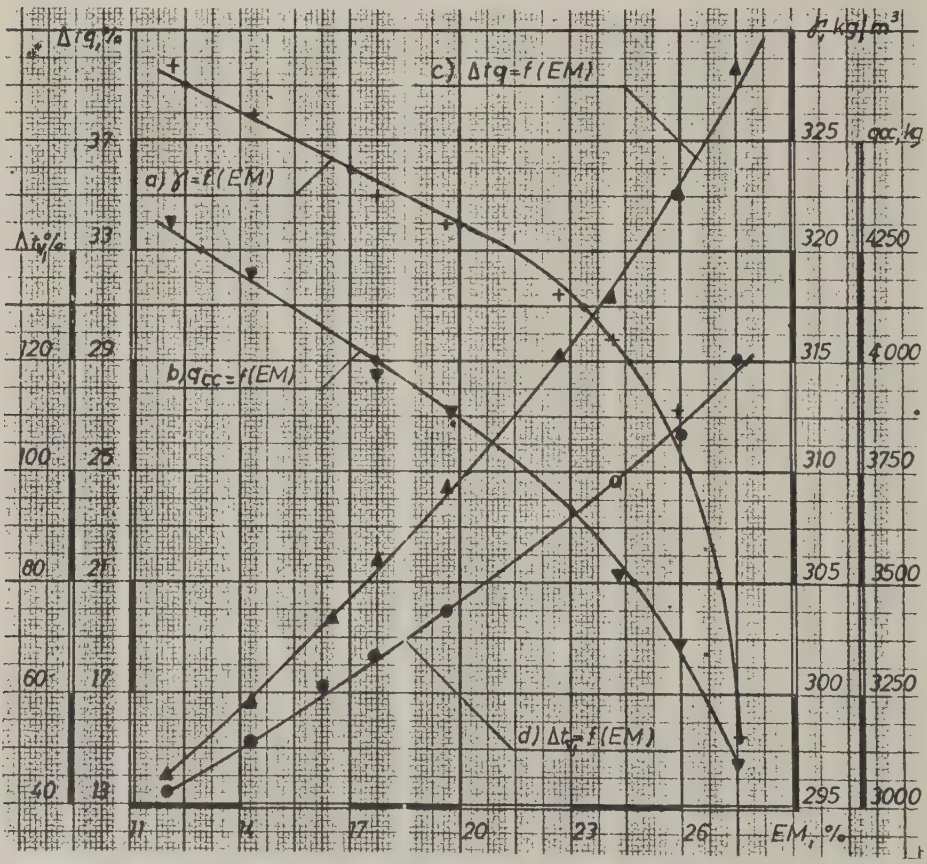

FIGURE 3. Variations in the volumetric weight of harvested vegetable mass (q_m), extraneous matter (EM) and loading coefficient of trailer (K) depending on the biological yield of sugarcane (Q_B).

The influence of extraneous matter content of harvested vegetable mass in its volumetric weight and weight of clean cane is shown in Fig 4.

From the analysis of the obtained data (Fig. 4 curves a and b) volumetric weight of harvested vegetable mass and weight of clean cane decreased with an increase in extraneous matter content. Thus, when extraneous matter content in the harvested vegetable mass reached 12.18%, its volumetric weight equally 328.55 kg/m^3 and when contents of extraneous matter was greater than 20%, volumetric weight abruptly decreased.

An increase from 2.5% to 3.0% in the extraneous matter content involved a 1% decrease in volumetric weight and a 4% decrease in clean cane weight. By knowing the relationship between extraneous matter content and the volumetric weight of elaborated vegetable mass as well as the weight of clean cane it was possible to determine the increase of transportation media as far as weight and volume was concerned.

According to the data from the Agronomics Laboratory of the Machinery Construction Research Center (CICMA) during 1977, the increase in weight and volume of transportation media was determined by the following formula:

$$\Delta t_q = \frac{100\ EM}{q_{cc}}$$

$$\Delta t_v = \frac{3.05\ EM}{100 - EM}$$

where: EM = extraneous matter % content of harvested vegetable mass in the trailer

q_{cc} = weight of clean cane in the trailer, kg

3.05 = constant multiplier depending on specific weight of sugarcane

By using formulas (2 and 3) the final value reached by the rate of transportation in weight and volume was found. Obtained data is shown in Table 2.

Based on data from Table 2, Fig. 4 was plotted which is the rate of change of transportation media in volume and weight depending on extraneous matter content in the harvested vegetable mass.

From Fig. 4 (curves c and d) it is seen that with an increase of extraneous matter content, there was an increase in weight and volume of transportation media.

Thus, when extraneous matter content in harvested vegetable mass reached

TABLE 2. Values of transportation increment depending on the extraneous matter content

No. of order	Weight of chopped clean cane q_{cc} kg	Volumetric weight of harvested vegetable mass kg/m^3	Extraneous matter content in vegetable mass		Increment in transportation	
			kg	%	in weight $\Delta^t q$	in volume $\Delta^t v$
1	4328.15	328.55	600.28	12.18	13.86	42.39
2	4197.98	326.34	697.05	14.24	16.60	50.64
3	4045.82	322.94	798.31	16.48	19.73	60.18
4	3975.70	322.52	862.09	17.84	21.68	66.14
5	3874.68	321.28	944.57	19.60	24.38	74.35
6	3693.18	318.10	1073.36	22.60	29.20	89.06
7	3590.21	316.39	1155.60	24.35	32.19	98.17
8	3476.96	312.99	1217.83	25.94	35.02	106.83
9	3203.90	297.98	1265.82	28.32	39.51	120.50

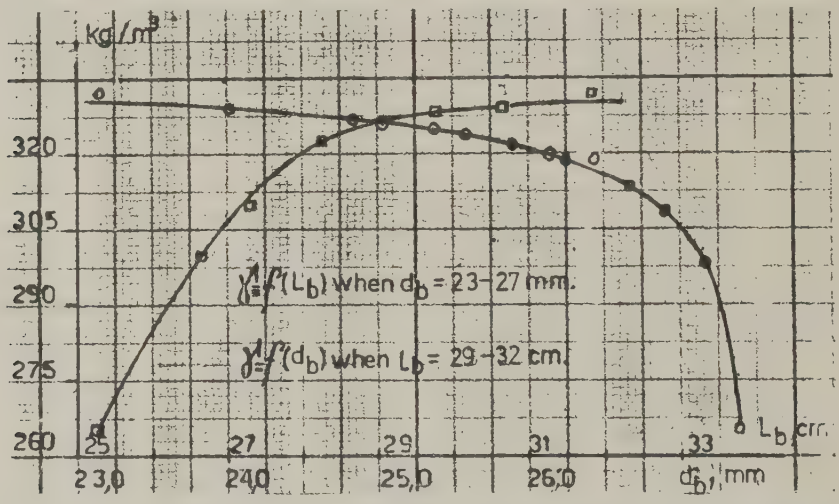

FIGURE 4. Variations of volumetric weight of harvested vegetable in trailers depending on length (l_b) and diameter (d_b) of billets.

14.24% the increase in weight and volume of transportation media was 16.6 and 50.64%, respectively, but when extraneous matter content reached 26%, the increase in volume and weight of transportation media increased twice as much. This means that a 1% increase in the extraneous matter content involved an increase in the rate of transportation in weight and volume from 1 to 1.25% and from 3.5 to 4%, respectively.

D. Influence of billet's length and their diameter in the volumetric weight of

harvested vegetable mass. Fig. 5 shows the influence of chopped stalks and their diameter on the volumetric weight of harvested vegetable mass.

The analysis of data (Fig. 5), showed that with an increase in the length of chopped billets, the volumetric weight of harvested vegetable mass decreased, on the other hand volumetric weight increased with the diameter.

It should be pointed out that an increase in the billet's length over 330 mm (when billet's diameter is from 23 to 27 mm) involved a rough decrease in the volumetric weight of harvested vegetable mass.

Thus, with equal stalk diameters and billets length from 250 to 320 mm, the volumetric weight of harvested vegetable mass decreased by 8% compared to billets with lengths equal to 250 mm.

Stalks with thickness up to 25 mm involved an increase in volumetric weight of harvested vegetable mass.

A continuous increase in stalks' thickness did not involve a significant increase in volumetric weight. Thus, when the thickness of stalks was 25 mm, volumetric weight of harvested vegetable mass was approximately equal to 323.56 kg/m^3, but when the thickness of stalks was equal to 26 mm, volumetric weight of harvested vegetable mass increased by 1.3% compared to stalks with a thickness of 23 mass. It is necessary to point out that volumetric weight of harvested vegetable mass depended not only on variation of parameters such as length of billet and stalk thickness, but also in the way in which vegetable mass was placed in the trailer and its density. Besides volumetric weight depends on the geometry of the trailer.

E. Determination of the necessary number of trailers to keep the uninterrupted work of combine harvesters.

In order to keep a steady flow of harvested vegetable mass to the sugarcane conditioning center or sugar mill, the whole productivity of cane trailers or trucks should be in agreement with feasible productivity of sugarcane combine harvester. In this case, the number of trailers (trucks) N should be optimum for the specific kind of work.

The minimum work output in the harvesting and transportation of the vegetable mass to be harvested should be taken optimization criterion. In other words, the problem is to find such a quantitative and qualitative relationship between combine harvesters and transportation media that allow to reduce interruptions to a minimum.

During harvesting of sugarcane with KPT-1 combine harvester, harvested vegetable mass was simultaneously loaded in the trailer (trucks) that travelled along

the side of the combine harvester. In this case, the necessary number N of trailers (trucks) for a continuous transportation of harvested vegetable mass was determined from the following formulas:

$$N\text{-}1 = \frac{W_{cp}}{Q_{lc}}\left(\frac{2L}{V_{tr}} + T_{ut} + T_{ft} \right)$$

where:

$$T_{lt} = T_{ft} = \frac{Q_{lc}}{W_{cp}}$$

and

$$T_{tt} = \frac{2L}{V_{tr}} + T_{ut} + T_{ft}$$

T_{lt} = total lapse of time to load a trailer, min.

Q_{lc} = load capacity of a trailer, kg

W_{cp} = capacity of combine harvester kg/min.

T_{tt} = transportation time, min

T_{ut} = time necessary to unload a trailer including other time, min

T_{ft} = loading time of a trailer, min

L = distance m from the cane field to the sugarcane conditioning center (sugar mill).

By means of the above formula the number of trailers for different combine capacities and distances from cane field to the sugarcane conditioning center (sugar mill) could be calculated. Transportation average speed was experimentally found to be 15 km/hour. Average loading time was 16.5 min and average unloading time 7.1 min. In practice it was very difficult by means of calculation to determine the number of trailers because it depended on cane yield, kind of combine harvester and its productivity as well as on the distance from the cane field to the sugarcane conditioning center (sugar mill).

For the above reason and in order to make a quicker determination of the number of trailers under production conditions a special nomogram has been devised (Fig. 6). The nomogram was made in the following manner. Fig. 6 in quadrant I shows change in combine capacity (ha/hour) depending on sugarcane yield 9 mt/ha. Quadrant II shows relationship between combine capacity (ha/hour) and harvested vegetable mass mt/ha. Quadrant III shows the relationship between amount of harvested vegetable mass and the distance from cane field to the sugarcane conditioning center. To use the nomogram, the following steps should be taken:

Based on the harvesting machinery available, yields, and distances for transportation of sugarcane, and also by means of Fig. 6, the number of transportation

media (trailers and trucks) necessary to carry the harvested vegetable mass could be determined. For example, for harvesting of sugarcane a KPT-1 sugarcane combine harvester should be used. The distance from the cane field to the sugarcane conditioning center (sugar mill) is 5 km. and sugarcane yield is 1000 MQ/ha. It is necessary to determine the number (N) of trailers for an uninterrupted transportation of harvested vegetable mass to the sugarcane conditioning center (sugar mill)

1. On scale of right upper quadrant mark out the chosen yield (1000 MQ/ha), and trace a vertical lineup to the intersection with the graph that characterizes the variation of combine capacity and from it we extend a horizontal line up to the intersection with the 1000 MQ/ha curve. From this point draw a vertical line down to the intersection with the S km. curve and from it trace a horizontal line up to the intersection with the vertical line corresponding to the number of trailers. In this way the necessary number of transportation media to be employed could be determined.

2. By adding one more unit to the above number (i.e. the trailer that's being loaded) we obtain the number N of trailers necessary to supply to the combine harvester; in this case, 5 trailers.

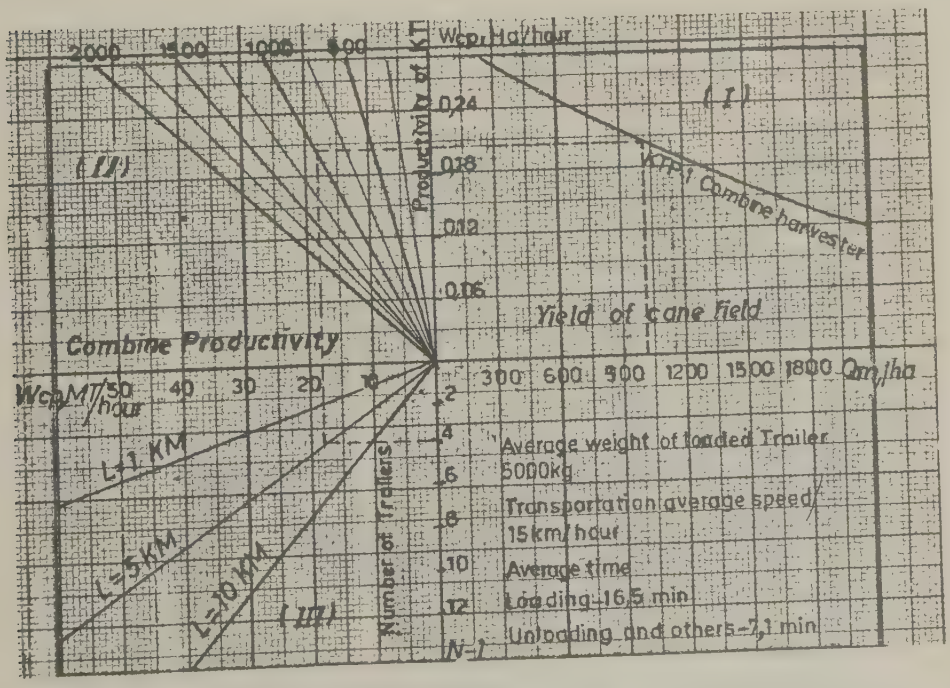

FIGURE 6. Nomogram for determining the number of trailers under production condition.

CONCLUSIONS

From the results of the data obtained from the investigation of the interrelationship among quality of chopped stalks, volumetric weight and loading coefficient of transportation media the following conclusions are established:

1. The degree of cleanliness of the harvested vegetable mass is influenced by the following factors.

   a) Morphological characteristics of variety, cultivation conditions (age, development degree, lodging of stalks), and grass covering

   b) Technical conditions of combine harvester, setting and qualification of operator

   c) Moisture degree of cultivation

2. With an increase in the biological yield from 106.5 MT/ha 157.7 mt/ha tops content decreased from 8.52% to 5.83%, trash decreased from 11.95% to 3.36% and suckers from 1.52% to 1.18%. A later increase in the biological yield produced unimportant variations in the components of extraneous matter.

3. With the increase in the biological yield form 106.5 mt/ha to 157.7 mt/ha volumetric weight of harvested vegetable mass increased from 297.98 kg/m^3 to 328.55 kg/m^3 while extraneous matter content in the harvested vegetable mass decrease from 28.32% to 12.32% to 12.18%.

4. With an increase in the extraneous matter content from 12.18% to 28.32% the transportation media in weight and volume also increased from 13.86% to 39.51% and from 42.90% to 120.50%, respectively, i.e a 1% increase in extraneous matter content increased the average of transportation rate ΔT_q from 1% to 1.25% and ΔT_v from 3.5% to 4.0%.

5. Results showed that with an increased billet's length from 25.17 to 33.64 cm, volumetric weight of harvested vegetable mass decreased from 333.71 kg/m^3 to 264.19 kg/m^3.

6. When the diameter of harvested stalk pieces decreased from 26.27 to 23.10 mm volumetric weight also decreased from 333.71 kg/m^3 to 264.19 kg/m^3

7. The analytic functions that were obtained and the nomogram made from these determined the necessary number of trailers for an uninterrupted work during harvesting of sugarcane.

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INVESTIGACION DE LA RELACION ENTRE LA CALIDAD DE LA CAÑA DE AZUCAR TROJADA, SU PESO VOLUMETRICO, Y EL COEFICIENTE DE CARGA EN LOS REMOLQUES

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y Miguel Dominguez

RESUMEN

Este articulo trata sobre los resultados de investigacion del peso volumetrico de caña de azucar trozada, un analisis de relacion entre

peso volumetrico y contenido de materia extraña, el rendimento biologico de la caña, el argo de los trozos y el coeficiente de carga de los remolques.

Basandonos en este analisis, llegamos a las siguentes conclusiones: el peso volumetrico de materia vegetal alimentada a la trozadora fluctua de 300 a 330 kg/m^3, el coeficiente de carga de remolque varia de 0.28 a 0.31 cuando el rendimiento de los campos es de 106.6 a 157 T/ha y el contenido de materia extraña fluctua entre 12 – 28%.

PERFORMANCE TESTING OF CHOPPER CANE HARVESTERS FOR CANE QUALITY

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ABSTRACT

The impact of mechanical harvesting on the quality of cane supply in Queensland is outlined and aspects of mechanical harvester design which have an influence on this are discussed.

INTRODUCTION

In times of excess supply of any commodity, buyers normally discriminate between sellers on the basis of quality (Kelly[20]). It is, therefore, essential that the export oriented sugar industry in Australia strives to meet the highest standards of sugar quality. One factor affecting the quality of output from a sugar mill is the quality of the input – the cane supply.

This paper describes the impact of mechanical harvesting on cane quality and performance testing of sugar cane harvesters carried out by BSES (Bureau of Sugar Experiment Stations) aimed at further improvement of the quality of the cane supply.

IMPACT OF MECHANICAL HARVESTING

Background

More than a decade has passed since the development and acceptance of the mechanical chopper harvester in Australia. As with mechanical harvesting of other crops, field layout and cultivation practice have had to be adjusted to make mechanical cane harvesting efficient and economical (Baxter[1] and Gaunt and Zagorski[14]). Conversion from harvesting whole stick cane to chopped cane created problems of cane deterioration (Price and Blyth[24]) but Egan[4] showed that one of the key factors in reducing deterioration of chopped cane was to minimize the delay between harvest and crush. Detailed studies of transport scheduling such as those of Murry[23] and of rostered harvesting (James and Hayes[19]) enabled mills to reduce the normal cut to crush delays to between two and 20 hours.

The Australian cane crop is not cut almost exclusively by chopper harvesters, the design of which has improved to the extent that lodged cane can now be

harvested with minimum loss of cane. Manual pick-up of sugar cane is no longer required. Harvesting is normally carried out in daylight hours only. Any further reductions in harvest to crush delay could only be achieved with extended harvesting hours (Foster[6]).

In 1973 and 1975, Australia's sugar cane growing areas had extremely wet harvest season. These extreme conditions caused harvesting delays (due to inability to operate in wet fields) and subsequent deterioration of cane burnt for harvest (McNeil and Inkerman[22]). Fuelling[10] noted that the design of the infield transport system restricted cane harvesting in wet fields and has reported on high flotation infield transport using weight transfer and large flotation tyres (Fuelling[12]). The deterioration of standing burnt cane also stimulated new investigations of all aspects of green cane harvesting: (deterioration Foster[7]), harvesting (Foster *et al.*[8]), processing (Foster[9]), trash disposal (Ridge *et al.*[25]).

Deterioration results in the conversion of sugar to polysaccharides, mainly dextrans (Egan[5]). Experiments by Henderson and Kirby[15] and Ivin and Bevan[18] showed the rise in dextrans was much more significant than the fall in sugar content (c.c.s). Although under normal harvest delays the decline in c.c.s. is a comparatively minor loss to the farmer, higher dextran levels are very deleterous to milling operations and sugar quality.

Even with cut to crush delays of less than 20 hours, the experiments of Henderson and Kirby[15], Ivin and Bevan[18] also showed more rapid deterioration of damaged billets and billets less than 250 mm long compared with undamaged billets greater than 250 mm. Foster[7] also showed less deterioration with green cane billets than burnt cane billets.

Extraneous matter in cane supply, (BSES[2]) i.e. tops, trash, roots and dirt, has increased with mechanical harvesting of the crops. Tops frequently comprise approximately two-thirds of the extraneous matter (Fuelling *et al.*[11]). They contain little sucrose and increase sugar production costs (Kirby and Kingston[21]). Trash increases fiber levels and reduces the crushing rate (Scott[26]) and lowers sugar quality in terms of color and filterability (Sloane and Rhodes[27]).

Dirt is normally only a small proportion of extraneous matter and the system of fines and bonuses is comparatively insensitive to significant changes in dirt levels which may be significant in the factory. As harvesters have improved to handle lodged crops and wet conditions, the amount of dirt in the cane supply has increased. The increase in the amount of dirt is of major concern to millers (Burgher and Nix[3]).

In order to provide a financial incentive to supply clean cane, in many areas the value of cane is adjusted by the imposition of penalties on the payment of bonuses related to extraneous matter levels.

HARVESTER TEST PROGRAMS

In 1977, BSES commenced performance testing of sugar cane harvesters with a view to defining factors which affected the quality of the cane supply (Henkel *et al*[16]). These tests were designed to investigate harvester performance in green and burnt cane in terms of:

1. billet length (average length and distribution)
2. billet damage (degree and type)
3. extraneous matter (levels and composition)

MATERIALS AND METHODS

The testing so far has been carried out in the northern region of Queensland using the variety Q90 which comprised 53% of the crop in 1978. This variety has a heavy green top, is relatively free trashing and has a sprawling habit which may lead to lodging in the cane field. Crop yields normally averaged between 80 and 100 t ha^{-1}. The crops were grown in rows spaced 1.4 to 1.5 m apart.

The cane supply is sampled with a portable chute (Fig. 1) directly from the harvester while operating. This chute is hooked on to the rear of the transporter bin and a flap above the bag diverts any extraneous material until a sample is required. To collect a sample, the transporter driver is signalled to speed up momentarily bringing the chute under the elevator outlet. The flap is opened by an operator following the bin and the sample collected in a bag. A quick release mechanism allows the operator to drop off the bag and replace it while the transporter is in motion. Samples are obtained without any interference with the operation of the harvester. Harvester ground speed is monitored with a wheel dynamometer attached to the rear of the harvester.

Due to variations along the row of the condition of the crop in terms of erectness, burnt quality, stalk length, etc., the stream material entering the bin is somewhat variable. It was found that, for samples of 15 to 20 kg., coefficient of variation for sound billets and extraneous matter varied from 7 to 14 and 22 to 31 per cent, respectively.

As a compromise between workload and precision, a standard of five samples each 15 to 20 kg has been adopted for each observation in harvester tests. Even with this density of sampling, it is necessary to repeat the test several times before general conclusions can be drawn regarding harvester performance.

Millable cane left in the field (scrap) is assessed from three plots each of approximately. 008 ha randomly located within the trial area. Cane removed by the topper and cane spilled from the transporters is excluded. The remainder is divided into billet cane (less than 500 mm) and whole stalk cane (greater

FIGURE 1. Portable chute attached to transporter for collecting cane samples.

than 500 mm). The amounts in each category are adjusted for juice losses due to damage by extractors and traffic (e.g. run over by harvester or transporter).

Cane samples are sorted according to data required for a particular test. Billet length is normally measured by sorting a sample of billets into size categories and calculating the mean length from the number in each category. Although this gives a reasonable assessment, it can be biased and for precise work, the length of each billet is measured.

Billet damage is a much more subjective assessment. Guidelines for distinguishing a sound billet from a damaged billet have been developed and are as follows:

A cane billet is classified as a damaged billet if —

1. It is broken or squashed such that there are numerous rind cracks and a portion of the cane is reduced to a pulpy condition, or

2. It has more than 400 mm^2 of rind removed exposing the interior of the stalk, or

3. It has "splits" (not including growth cracks) in the rind totalling more than 80 mm. However, rind cracks less than 40 mm are not regarded as "splits".

For extraneous matter analysis the components are defined thus:

Tops — that part of the section of the stalk above highest developed internode which can readily be broken off by hand. Normally of billet or part billet length.

Trash — dry and green leaves and leaf sheaths (not included in tops) This category includes weeds, grass etc.

Roots — true roots (excluding dirt) which extend from the internodes of the cane stalk above or below ground.

Dirt — all soil and stones included free within the sample plus similar material removed from the roots or billets.

RESULTS

Harvester performance

In 1977, the Toft 4000, Toft 6000, Massey Ferguson 205, and Class Libertadora 1400 were tested in green and burnt cane. The tests were generally carried out in erect crops (yields 70 to 105 t/ha^{-1}) with well maintained machines and good operators.

In each test the harvester was initially operated at the normal harvest speed selected by the operator for the particular condition. This ranged from 5 to 7 km/hr^{-1} in burnt cane and 4 to 6 km/hr^{-1} in green cane. Where possible, harvesters were then operated at 2 km/hr^{-1} above and below the normal harvest speed.

Fig. 2 gives a break-up of the cane supply harvested at the normal speed in terms of sound billets, damaged billets and extraneous matter.

The results of the tests reported by Fuelling *et al*[11] can be summarized as follows:

1. Over the range of speeds tested, speed of operation had little effect on the quality of the cane supply for well maintained machines with sharp chopper knives.

2. Speed of operation had no effect on the amount of millable cane left behind. This was mainly dependent on ground conditions.

3. Large variations in billet length were primarily due to different chopper gearing fitted to the harvester. With the Massey Ferguson 205 some shortening of billets was noticeable when cutting green cane.

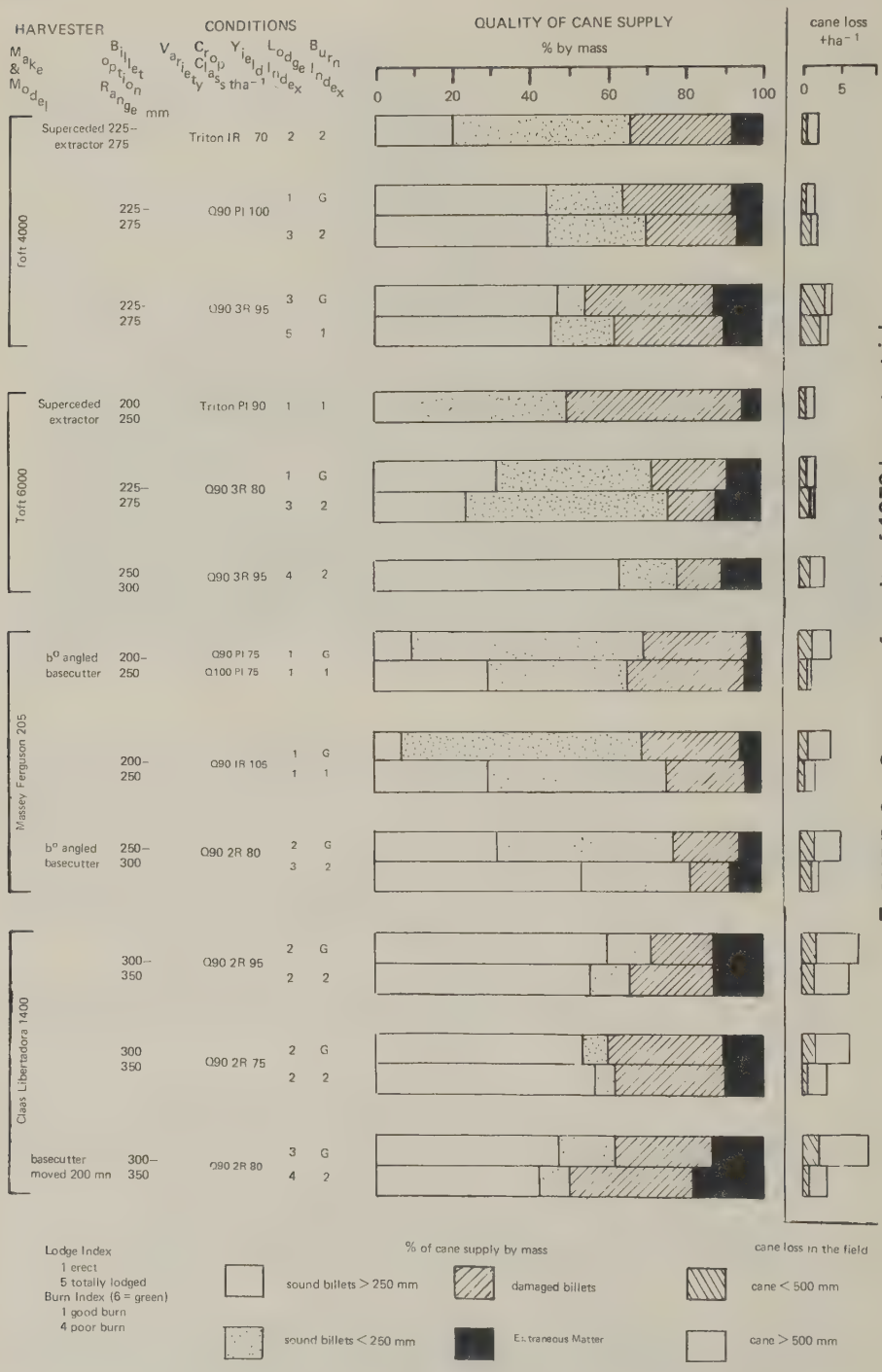

FIGURE 2. Summary of results of 1978 harvester trials

4. Operator attitude to maintenance and operations was a key factor in determining the quality of the cane supply.

5. Cultivation practices and field conditions had a large influence on the quality of the cane supply

6. The Claas 1400, Massey Ferguson 205, Toft 4000 and Toft 6000 were all capable of harvesting erect crops of Q90 cane in green condition with extraneous matter levels similar to those of burnt cane. However, output was reduced by 30 to 40 per cent.

Effect of basecutters setting on dirt in the cane supply

In 1978, a series of case studies (Henkel *et al*[17]) were carried out with a Toft 6000 harvester which had twin horizontal basecutters (similar to those fitted by Massey Ferguson and Claas). These were operating in ratoon crops in which soil in the row is hilled up at least 50 mm above the interspace. The machine had adequate power to cut below ground level. In the earlier testing (Fuelling *et al*[11]) it was noted, that, in physical sorting of cane samples, a significant amount of dirt adhered to the cane billets was not included in the extraneous matter assessment. A washing step was therefore introduced. The results in Table 1 show that:

1. Cutting below ground level considerably increased the amount of dirt in the cane supply;

2. Normal physical analysis of cane samples measured less than half the total quantity of dirt;

3. Dirt levels increased significantly in wet and lodged crop conditions; and

4. Cutting below ground significantly reduced loss of millable cane in lodged conditions.

Knife life studies

There are two different systems for chopping cane used in cane harvesters in Australia. Massey Ferguson and Claas machines are fitted with a drum chopper which gives a scissor-type cut. The Toft machines are fitted with the single rotating chopper knife which gives a chop-type cut. The blades on the drum choppers scrape together at each cut giving a self-sharpening action when correctly adjusted. The rotating chopper used in the Toft system is not self-sharpening but has a simple change procedure allowing regular replacement.

The change in billet quality with tonnage cut after new chopper knives that have been fitted was used as an indicator in knife studies carried out on current model harvesters in 1978.

TABLE 1. Test conditions, measured dirt levels (% of the total sample) and cane left in the field (t/ha^{-1})

Study	Crop condition	Soil condition	Soil type	Basecutter setting *	Dirt (%) of sample			Cane left in field (t/ha^{-1})			
					Physical analysis	Wash analysis	Total	Whole stalk	Stubble	Butt	Total
1	erect	dry	yellow earth	A	0.03	0.19	0.22	4.56	6.46	3.0	14.02
				G	0.08	0.31	0.39	1.33	–	3.0	4.33
				B	0.63	1.08	1.71	0.33	–	–	0.33
2	erect	wet	yellow earth	A	0.04	0.50	0.54	0.85	4.58	3.21	8.63
				G	0.00	0.68	0.68	0.37	–	3.21	3.58
				B	2.30	4.15	6.45	0.12	–	–	0.12
3	lodged	dry	yellow earth	G	0.16	0.41	0.57	8.30	–	2.75	11.05
				B	3.09	2.01	5.10	0.72	–	–	0.72
4	erect	dry	red volcanic	A	0.00	0.55	0.15	0.98	2.68	2.16	5.82
				G.	0.00	0.31	0.31	0.18	–	2.16	2.34
				B	0.04	0.52	0.56	0.06	–	–	0.06

**A = 50 mm above ground level; G = ground level; B = 50 mm below ground level*

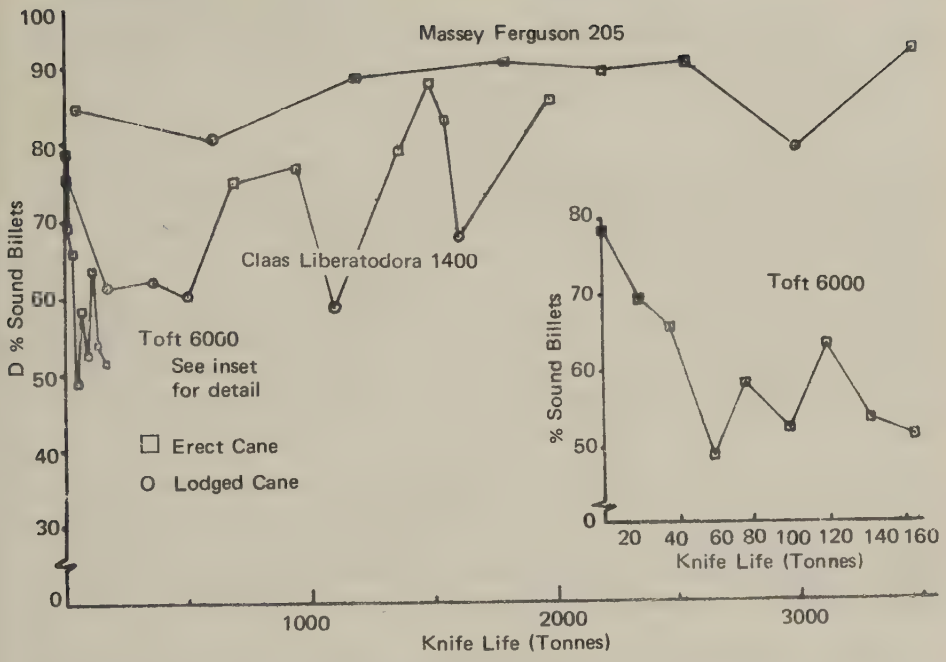

FIGURE 3. The relationship between percent sound billets and the tons of cane cut follow chopper blade replacement

Manufacturers advised their recommended change interval for the knives and the tests were extended well beyond these intervals. All tests were carried out in stone-free, clay loam soils in the northern region (Fuelling and Henkel[13]). Fig. 3 shows levels of sound billets found in typical tests on each make.

The conclusions from the tests were:

1. Massey Ferguson harvester produced the most consistent supply of sound billets.

2. The Claas Libertadora 1400 harvester produced a lower level of sound billets. This could be due to:

   (a) the combined feeding and chopping function of the chopper

   (b) the wider throat of the machine

   (c) the position of the chopper system close to the basecutter

   (d) the action of the side cutter knife used in lodged crops

3. Of the three types of machines tested, the Toft harvester gave the lowest level of sound billets. The importance of regular knife replacement was obvious.

4. Lodged crops reduced the percentage of sound billets in the cane supply.

DISCUSSION

As the quality of the cane supply affects sugar quality, the importance of producing cleanly cut, undamaged billets of a length optimum for the area can not be overlooked. Harvester design must be such that these criteria can be met without undue maintenance problems for the machines.

Tests have shown that current model harvesters can achieve a very low rate of cane loss in the field when cutting erect crops. However, significant losses occur in badly lodged cane. Although these losses can be reduced by cutting below ground level, the increase in the amount of dirt in the cane supply can not be tolerated.

No matter what system are used for gathering up the crops it seems likely that the harvest of any heavily lodged crops must result in a certain amount of stalk damage and breakage even before the cane reaches the cutting mechanism of the machine. In erect crops, however, damage to the billets can be minimized by harvester design characteristics.

From the work reported in this paper, it is obvious that machines with self-sharpening double drum choppers can produce billets of high quality with long periods between blade replacement under reasonably stone-free conditions. This was not the case with machines utilizing the single rotating knife system. While frequent replacement of the latter type overcomes the billet damage problem to some extent, operators of the machines must be prepared to make the knife exchange at the appropriate intervals. Frequently, this does not happen in commercial practice.

However, it may be argued by some that in fields where stones are a problem the single rotating chopper with its simplicity of change is a better proposition as operators of the drum choppers would be less likely to halt the harvest to attend to minor blade damage. Limited tests indicated that with minor blade chips with MF205 could still produce billets of reasonable quality.

However, it is considered that easy adjustment and replacement of chopper knives should be an important aspect of design of all harvesters. Operators should be able to keep their machines in top condition with minimum of lost time due to knife maintenance essential for a high quality cane supply.

CONCLUSIONS

There have been tremendous advances in harvester design since mechanical harvesting became accepted into the Queensland sugar industry. Machines now have the power and ability to cut heavy lodged crops, to remove much of the extraneous leaf material from the crop and to produce cane billets of acceptable quality. However, to achieve the level of efficiency of which harvesters

are capable, attention must be made to the condition of the field and harvester operators must have a full appreciation of the requirements for a clean cane supply.

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PRUEBA DE FUNCIONAMIENTO DE LA MAQUINA COSECHADORA CON RELACION A LA CALIDAD DE LA CAÑA DULCE OBTENIDA.

T. G. Fuelling

RESUMEN

El efecto en la calidad de caña dulce cosechado en Queensland por medio de una maquina cosechadora se delinea en esta presentación, y se discuten ademas otros aspectos en el diseño del mecanismo de la cosechadora que influe tal calidad.

EXTRAPOLATION OF TRASH EFFECT ON POL LOSSES IN BAGASSE

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ABSTRACT

The trash content of sugarcane from hand-cut mechanically loaded and from mechanically-cut by TOFT ROBOT CH 364 harvesters was determined for wet harvest period (December-March) and dry hot harvest period (end of March-June) in Iraq. Extrapolation of trash effect on pol (sucrose) losses in bagasse was estimated. The effect of the desiccant Gramoxone on trash % cane under field conditions was also studied.

The annual total trash averaged 11.9% for both hand and mechanically-cut cane during 1976-77. During 1977-78, this annual average was 9.9% for hand-cut and 9.6% for mechanically-harvested cane. It was 14.5 and 11.8 for hand and mechanically cut cane during 1978-79.

A wide difference was apparent in the trash % as sugarcane was either harvested during wet or dry periods. Hand-cut untopped cane during wet periods presented an average of 24.5% and 14.9% trash for November, 1978 and March, 1979, respectively. During June, 78 dry periods, this average decreased to 4.7%. The mechanically harvested cane showed an average of 17.3 and 3.3 trash % cane for November, 1978 and June, 1979 harvest, respectively.

Each 1% trash in cane significantly increased fiber % milled cane by 0.32% and 0.22% in cane harvested during wet and dry periods, respectively. This increase in fiber % milled cane was significantly correlated with trash % cane and resulted in a loss of 0.24 and 0.21 kg sugar/ton of cane for each unit increase in trash % cane. Gramoxone – treated burnt-cane presented 2.37% trash; 21 days after treatment during December, while untreated burnt-cane presented 13.67% trash. No drop in juice quality was observed up to 11 days after treatment. Steps for management as to reduce trash and its effect on pol losses through bagasse are given and discussed.

INTRODUCTION

The harvest season in Iraq, usually extends from mid-November to late May or early June, coinciding with the rainy season at the incline phase, and high temperature during the decline phase. The area receives an average annual rainfall of 161 mm, 103 mm or (62%) of which falls during winter (December to February). The summers are absolutely dry. Due to rainfall and high relative humidity (78%) during winter, poor burns and mechanical harvesting result in high trash and extraneous matter content at the beginning of the harvest season. Towards the end of the harvest season, dry cane leaves and weeds account for most of the trash content.

One of the most serious disadvantages of milling cane is the extraneous matter such as green or dry leaves, tops, soil, stones, water sprouts and any other materials brought to the mill (Mayoral and Vargas[5]). Many studies have been made on the economics and the adverse effects of extraneous matter on harvesting, loading, transportation and factory operations (Birkett[1], Fernandes *et al*[4], Mayoral and Vargas[5], Rozeff[8]). Fernandes *et al*[4] grouped these effects depending on the factory operations affected:

(a) Reduction of milling capacity, sucrose extraction, juice purity and recoverable sugar.

(b) Increase of maintenance costs, molasses quantity and purity, undetermined losses, filter cake losses and equipment wear.

An appraisal of trash effect requires a measure of the quantity of trash entering the mill with the cane and the percent fiber in the trash. Payne[7] stated that this, in most areas, is very important factor for dry leaves have four times as much fiber as the mature cane has and tops up to two times as much. Birkett[1] showed the relative proportions of clean cane, tops and trash to be 84%, 11%, and 5%, respectively. Analysis of trash showed a mean solid content (fiber) of 60.95%. Tambosoco *et al*[10] reported that immature tops are the major components on weight basis, of the total trash and weighed from 6.35 up to 10.86%.

Increasing usage of mechanical loading and combine harvesters aggravates the trash problem, especially under unfavorable weather conditions. In Iraq, 80% of the crop is mechanically harvested and the other 20% is hand-cut and mechanically loaded. Trash content has been reported worldwide to vary between 2.02% and 20% (Fernandes *et al*[4]). Mechanical, physiological, biochemical and agricultural standards have been practiced throughout the world to minimize trash % before harvest. Techniques such as crop-logging, maturity control, ripening, desiccating, burning cane before harvest and using trash-extractor fans are gaining wide acceptance among cane growers. Although desiccants are most effective in reducing trash, they have no direct beneficial effects on juice quality (Evans and Bates[3]). On the contrary, low juice quality may result from using desiccants (Davidson[2], Evans and Bates[3]).

An assessment of the trash problem in Iraq, as the harvest season progresses, and its effect on pol losses in bagasse is described in this study on the assumption that reduction in trash would result in large savings derived from avoiding transport costs of trash, improved mill efficiency and improved sugar recovery due to lower fiber milled and lower losses in bagasse. Also, the effect of the desiccant paraquat, commercially known as Gramoxone, on trash content was determined to improve burns and reduce the trash content entering the mill at the beginning of the harvest season.

MATERIALS AND METHODS

The trash determination was carried out under normal operational field conditions for hand-cut mechanically loaded cane (hand-cut) or for mechanically-harvested cane by TOFT ROBOT CH 364 (cut-chop-load) harvesters. Trash % cane for both hand-cut and mechanically-harvested cane is presented for 1976-77 season. In 1977-78 trash % for each treatment were presented. The same was done for 1978-79 harvest season.

Samples consisted of 25-40 kg of hand-cut cane (whole stalk) or mechanically-harvested billets taken from the bins at the factory site. Twenty sample amounting to 500-800 kg were analyzed daily throughout the milling season. Each stalk and billet was manually cleaned, and the trash was weighed to the nearest 0.1 kg for each sample. Total trash which includes immature tops, leaves, soil and other impurities such as roots, weeds, stones, etc. was determined for each type of harvest. Daily averages were recorded and monthly averages were presented for both hand-cut and mechanically-harvested cane. No attempt was made to separate trash components.

Since the customary fiber analysis was made on clean millable stalks with no trash, the daily fiber entering the mill was recorded as fiber % milled cane during 1977-78 milling season. Regression analysis (Snedecor[9]) for the fiber % milled cane on trash % cane was fitted for the wet harvest period (rainy period – December 3, 1977 to March 20, 1978) and foe the dry harvest period (March 21 to June 19, 1978) due to a decrease in total trash resulting from better burns in the second period. Extrapolation of pol losses in bagasse was presented for both periods based on the factory average results of the 1977-78 milling season.

An augmented block trial of Gramoxone (1:1 di-methyl-4, 4-bipyridylium dimethyl sulphate) effect on trash % cane was carried out on NCo 310, second ratoon crops at eleven months of age. Gramoxone at 6 liter (commercial formulation) in 160 liter of water per hectare was sprayed on Dec. 8, 1977 with a boom spray covering about 10 m strip. Samples were collected directly before spraying, at 2, 7, 8, 11, 16, 18 and 21 days after treatment. Locations from treated and/or untreated strips were randomly selected at each sampling date. Four replicate-samples of 5 canes, amounting to 20 stalks, were collected for analysis. Samples were weighed, detrashed and analyzed for trash % cane,

leaf and sheath moisture content. Then the stalks were grounded with a motor driven 3-roller Cuban mill and the juice was analyzed for brix, pol purity, reducing sugars, fiber % cane, EC and pH according to Meade[6].

RESULTS AND DISCUSSION

The results showed that the total trash % for both types of harvest ranged from 5.6 to 19.8 during 1976-77 harvest season. The averaged percentage of the total trash decreased from 15.9 to 10.6 for November and April harvest, respectively, with an annual average of 11.9% (Table 1). The decrease was more conspicuous during the 1977-78 harvest season, when harvest was extended during May and June. The same trend was obtained 1978-79 harvest season.

Hand-cut showed a range of 3.0% to 23.8% trash with an average of 21.2% and 4.7% during wet and dry harvest periods, respectively. Mechanically-harvested cane showed a range of 3.5% to 22.2% with a monthly average decreasing from 15.6% to 4.5% during wet and dry harvest periods as the season progressed from December, 1977 to June, 1978 (Table 1). The total annual average (for wet and dry harvest periods) of trash was 9.9% for hand-cut cane and 9.6% for mechanically-harvested cane. It was 14.5 for hand-cut and 11.8 for mechanically-harvested cane during 1978/79 harvest season.

Regression analysis of fiber % milled cane on trash % cane (Table 2) showed that every 1% trash during the wet harvest period contributed 0.32% fiber to fiber % milled cane. The fiber % milled cane ranged from 16.33 to 22.27 at 3% and 21% trash, respectively. Each 1% trash during the dry harvest period added 0.22% fiber to the fiber % milled cane. The fiber % milled cane ranged from 16.44 to 18.20 at 3% and 11% trash, respectively, during the dry harvest period. This increase in fiber % milled cane due to trash was highly significant throughout the harvest season. A highly positive significant correlation ($r = 0.727^{**}$) was apparent for trash effect during the wet harvest period. The correlation was moderate ($r = 0.464^{**}$) for the dry harvest period. The cumulative fiber % milled cane was linear and proportional to the trash % cane between 3% and 21% (Table 2).

Actual factory results (Table 3) showed that the average trash % cane and the average fiber % milled cane were 12-21 and 19-26 during the wet harvest period and 6.08 and 17.16 during the dry harvest period, respectively. Fiber % clean cane (no trash) averaged 13.41 and 14.31 during the wet and dry harvest periods, respectively. The fiber % clean cane during the dry harvest period ranged from 13 to 16, and from 11.5 to 14.0 during the wet harvest period. This led to the higher fiber % bagasse and pol % bagasse during the dry harvest period as compared to those during the wet harvest period (Table 3).

Extrapolation of trash % cane effect on bagasse % cane, and pol losses in bagasse is presented in kg/ton cane and the difference due to trash increment was calculated (Table 4). Although, clean cane showed more or less the same

TABLE 1. Trash % cane in hand-cut mechanically loaded cane and mechanically-harvested (Cut-chop-load) cane during 1976 1979 harvest seasons

Month	1976/77 Season		1977/78 Season				1978/79 Season			
	Hand & Mech.-Cut		Hand-Cut		Mech-Harvest		Hand-Cut		Mech-Harvest	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Nov.	14.0-18.0	15.9	–	–	–	–	–	–	–	–
Dec.	6.5-17.9	12.1	18.5-23.8	21.2	13.3-21.2	15.6	18.1-27.3	24.5	16.7-17.6	17.3
Jan.	5.7-17.8	11.5	8.2-19.6	12.4	8.3-20.0	13.2	6.7-22.5	10.6	7.1-21.4	12.5
Feb.	7.2-17.0	11.0	8.3-13.3	11.3	8.3-22.3	11.0	6.7-23.1	12.9	9.1-14.3	12.0
Mar.	4.6-14.6	10.6	5.6-16.7	9.5	4.0-15.5	10.4	5.0-21.4	14.9	7.2-17.5	13.4
Apr.	6.5-19.8	10.6	3.2- 9.1	5.7	4.5-11.8	6.2	3.3-13.5	10.5	4.8-12.8	9.6
May	–	–	3.0- 7.7	5.1	3.7-11.1	6.7	5.6-23.0	13.9	2.4-19.1	9.7
Jun	–	–	4.5- 5.0	4.7	3.5- 3.3	4.5	–	–	2.0-12.5	8.3
Avg.		11.9		9.9		9.6		14.5		11.8

bagasse % cane during the wet and dry harvest periods, pol losses during the dry period for clean cane was 17.6% more than that for the wet period. Bagasse % cane increased from 40.00% to 46.46% and from 37.22% to 41.21% and 3% to 11% trash during wet and dry periods, respectively. During the wet period, bagasse % cane reached 54.57 for maximum trash of 21%.

Pol losses amounted to 19.04 kg/ton cane milled with 21% trash during the wet period and 17.14 kg/ton cane milled with 11% trash during the dry period. Pol losses in bagasse from clean cane was 11.46 and 13.48 kg/ton cane milled during wet and dry periods, respectively (Table 4). Considering 3% as an acceptable trash for milling, an increment of 0.24 kg sugar/ton cane milled was lost for each 1% increase in trash during wet period. This value was 0.21 kg sugar/ton cane milled during the wet period. This showed that sugar losses amounted to 1.0 kg/ton of cane when milled with dry trash equal to 47.6 kg or green trash equal to 41.6 kg/ton cane. Table 4 shows that the relationship between trash and fiber % milled cane is not straight towards the end of the harvest season. Furthermore, it showed a minimum loss of sugars in bagasse at 3% trash.

Gramaxone was very effective in desiccating the leaf moisture from 64.8% to 47.3% without affecting sheath moisture. Sheath moisture was 78.8% and 76.7% for treated and untreated cane, respectively, 18 days after treatment in December. This resulted in good burns of the treated cane without affecting juice quality up to 16 days after spraying. Eleven days after spraying, all leaves were dry enough for good burns. Trash % in the Gramaxone treated burnt-cane was tremendously reduced to 2.37%. It was 13.67% for the un-treated burnt-cane (Table 5).

Apparent purity showed a light increase associated with a decrease in the reducing sugars % sucrose for the Gramoxone-treated plants, 8 days after spraying. Up to 11 days after spraying, no drop in juice quality of the treated plants was observed. After 18 days, a 3.5 points drop in purity with a marked increase in reducing sugars % sucrose was apparent in the Gramoxone-treated plants as compared with those for untreated plants (Table 5).

A trash content of 3% is a pre-requisite for good milling ensuring more optimum recovery and factory through put. The high trash % during wet harvest period in Iraq increases the fiber % milled cane and adds to sugar losses through bagasse. Drying dry hot harvest period, the increase in fiber % clean cane is the main cause for sugar loss in bagasse, showing a tendency to pithiness with loss of juice. This leads to low % call rupture and less extraction, resulting to high pol % bagasse.

The high trash % was due to immature unriped cane brought about by the short growing season for ratoons due to warm rainy weather, improper topping for mechanically harvested lodged cane, untopped and hand-cut cane, and/or uprooted stools with adherent soils resulting from poor

TABLE 2. Fiber % milled cane as a function of trash % cane for wet harvest period (Dec.-March) and dry harvest period (March-June) during 1977/78

Trash % Cane	Fiber % Milled Cane	
	(3 Dec.-20 March) Wet harvest period	(21 March-19 June) Dry harvest period
3	16.33	16.44
4		16.66
5	16.97	16.88
6		17.10
7	17.66	17.32
8		17.54
9	18.31	17.76
10		17.98
11	18.97	18.20
13	19.63	
15	20.29	
17	20.95	
19	21.61	
21	22.27	
Regression Coef. (b)	*0.32***	*0.22***
Correlation Coef. (r)	*0.727***	*0.464***
Reg. Equation	*Y = 15.37 + 0.32X*	*Y = 15.78 + 0.22X*

*** Highly significant at the 0.01 level of probability*

growing conditions and moist soils. Also, the high weed infested fields may continue to the high trash content. The high trash % in the hand-cut untopped cane was mainly due to immature tops and green leaves and increases the quantity of bagasse during wet harvest periods. During hot harvest periods, dry leaves resulted to good burns and have less effect on bagasse % cane. Burning of dry leaves before harvest may explain the added low 0.22 fiber % milled cane for each 1% extra-trash during the dry harvest period.

The high trash % significantly increased the quantity of bagasse for each

TABLE 3. Maximum, minimum and average factory figures for trash % cane, fiber % clean cane, fiber % milled cane, fiber % bagasse for pol % bagasse for wet and dry harvest periods during 1977/78

Harvest Period	(3 Dec.-20 March) Wet harvest period	(21 March - 19 June) Dry harvest period
Trash %		
Max.	19.87	9.51
Min.	7.09	3.88
Average	12.21	6.29
Fiber % C. Cane		
Max.	14.00	16.00
Min.	11.50	13.00
Average	13.41	14.31
Fiber % M. Cane		
Max.	22.07	18.92
Min.	17.00	16.02
Average	19.28	17.16
Fiber % bagasse		
Max.	45.05	66.21
Min.	36.36	33.65
Average	40.83	44.17
Pol % bagasse		
Max.	4.80	5.90
Min.	11.60	3.20
Average	3.49	4.16

TABLE 4. Extrapolation of trash % cane on bagasse % cane[1] and pol losses (Kg/ton cane) in bagasse

Trash % cane	Bagasse % cane	Pol losses Kg/ton cane	Difference[2] Kg/ton cane
		(3 Dec.-20 March) Wet harvest period	
0	32.84	11.46	—
3	40.00	13.96	2.50
5	41.56	14.50	0.54
7	43.23	15.08	1.12
9	44.84	15.66	1.70
11	46.46	16.21	2.25
13	48.08	16.78	2.82
15	49.69	17.34	3.38
17	51.31	17.91	3.95
19	52.93	18.47	4.51
21	54.57	19.04	5.08
		(21 March-19 June) Dry harvest period	
0	32.40	13.48	—
3	37.22	15.48	2.00
4	37.72	15.69	0.21
5	38.22	15.90	0.42
6	38.71	16.10	0.62
7	39.21	16.31	0.83
8	39.71	16.52	1.04
9	40.21	16.73	1.25
10	40.71	16.94	1.46
11	41.21	17.14	1.66

1 — Calculated as: $\frac{\text{Fiber \% Milled cane}}{\text{Average fiber \% bagasse}}$

2 — Difference was subtracted for 3% trash

ton cane milled, and consequently increases sugar losses through bagasse. Hence this loss was governed by the weight of the bagasse per unit cane and the percentage of pol in the bagasse. Besides, this loss of sugar in bagasse as Payne[7] mentioned has effects which include difficult milling, lower purities, bad clarification, slow crystallization, more viscous massecuites and low over all production rates.

The Gramoxone results showed that desiccating leaves for the first six weeks of harvest was very effective in reducing trash % cane to an acceptable level of processing. However, the quality of the treated cane commence to drop, 11 to 18 days after spraying. This necessitated harvesting treated cane within 11 to 16 days after treatment and before any sucrose reduction and/or cane regrowth is resumed.

TABLE 5. Gramoxone[1] effect on trash % cane[2], purity and reducing sugars % sucrose (RS % S)

Days after spraying	Treated[3]			Untreated[3]		
	Trash % cane	Purity	RS % S	Trash % cane	Purity	RS % S
Before Spraying	32.84	89.18	1.17	32.84	89.18	1.17
2	27.10	89.10	1.90			
7	25.76	89.46	1.55			
8	21.42	91.13	0.87	21.46	88.82	1.32
11	13.69	89.32	1.05	12.33	86.20	2.76
16	14.50	89.67	1.28	16.47	91.07	0.87
18	12.04	85.48	2.36	16.53	89.01	0.99
21[4]	2.37	88.93	1.70	13.67	89.51	1.50

1. *6 Liter commercial formulation in 160 liter water/ha in a boom spray*
2. *Includes green and dry leaves, tops, roots. . . etc., topping was done at the snapping point resulting in a high-weight tops before spray, topping was done at the last visible dewlaps, 11 days after spray*
3. *Readings are average of 4 samples of 20 stalks each*
4. *After burn*

CONCLUSION

The excessive trash could be reduced by proper crop management so as to obtain a desirable cane at harvest. This management includes:

(a) Limiting the harvesting season to 120 days (mid-December to mid-April).

(b) Application of crop log and maturity control for harvest priorities.

(c) The use of desiccants and ripeners for the early few weeks of harvest and/or the use of trash dry-cleaners throughout the harvesting season.

(d) Cutting the desiccant-treated cane within 16 days after treatment.

(e) Avoiding soil high moisture content at harvest by withholding irrigation 30-45 days before harvest. This will restrict vegetative growth and result in good burns. Sucrose accumulation can also be enhanced because of forced ripening. Besides, soil compaction can be minimized under the heavy harvest and transport machines.

In conclusion, trash reduction helps to increase the rate of harvesting, loading, transportation, milling extraction through reduced fiber, and helps

boiling house recovery by raising purities in crushed cane. The result is greater factory throughout, less mechanical wear and depreciation of mill rollers and shorter milling season as was stated by Mayoral and Vargas[5], Payne[7] and Rozeff[8]. These direct results and side benefits minimize the high economic losses due to trash in cane.

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EXTRAPOLACION DEL EFECTO DE BASURA SOBRE PERDIDAS POL EN BAGAZO*

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RESUMEN

En Iraq se determinó el contenido de basura en la cosecha de caña de azúcar por corte manual y carga mecánica y de corte mecánico por cosechadoras TOFT ROBOT CH 364 durante un periodo lluvioso (diciembre-marzo) y un periodo, seco y caluroso (fines de marzo-junio). Se estimó la proyeccion de los efectos de basura sobre perdidas de pol (sucrosa) en el bagazo; tambien se estudio en el campo el efecto del desecante Gramozone en % de basura. El total anual de basura durante 1976/77 alcanzó un promedio de 11.9% para ambos cortes de caña – manual y mecánico. Durante 1977/78 el promedio anual fué 9.9% para corte manual y 9.6% para corte mecánico. Se hizo aparente una diferencia alta en el % de basura ya que la caña fué cosechada durante periodos lluviosos o secos. El coste de caña manual, sin descogollar, durante periodos lluviosos dió un promedio de basura de 21.2 y 9.5% en noviembre y marzo respectivamente. Durante periodos secos este promedio se redujo a 4.7% la caña cortada mecanica, y 4.5% en los meses de noviembre y junio respectivamente.

Cada 1% de basura contenida en la caña aumento significativamente el % de fibra en caña molida por 0.32 y 0.22% en caña cortada durante periodos lluviosos y secos respectivamente. Este % de aumento de fibra en caña molida fué correlacionado significativamente con el % de basura en la caña y resulto en una perdida de 0.24 y 0.21 kg de azúcar/ton de caña por aumento de basura en la caña por unidad. La caña quemada tratada con Gramoxone revelo 2.37% de basura a los 21 dias después del tratamiento, mientras que caña quemada sin tratamiento reveló 13.67% de basura. No se observó baja alguna en la calidad del jugo hasta 11 diás después del tratamiento. Procedimientos para administración con el fin de reducir la cantidad de basura y sus efectos en la disminución de pol por causa del bagazo son dados y discutidos.

EFFECT OF WATER TABLE LEVEL ON CANE PRODUCTION

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ABSTRACT

A series of experiments were made on fields of both Casa Grande and Cartavio Cooperatives, Chicama River Valley, in the northern coast of Peru, to evaluate the effect of the dynamic water tables on cane production.

The evaluation was performed starting with the criterion of relating cane production to the persistence of water table at levels of 60, 80, 100, 120, 140 and 160 cm. Significant correlations were found between cane production (t/ha) and the persistence of water table levels at depths of 60, 80, 100, 120 and 160 cm, and a highly significant correlation at 140 cm.

Maximum cane yields were obtained when groundwater levels were kept below 140 cm depth.

INTRODUCTION

Although the effect of water tables on the growth and production of crops has been extensively studied, only very few research works have been made on the sugarcane crop.

Wilkins and Ateshian[7] studied the relationship of average water tables of 76, 103 and 110 cm depth with cane quality. They found out that water table fluctuations have a negative effect on production when the average depth of water table is less than the optimum one; while at greater average depths the fluctuations are not dangerous, provided that salinity levels are not toxic. Theoretically, they established the optimum production at 146 cm depth. Gosnell[2] made an experiment on static water tables, keeping the levels at depths of 25, 50, 75, 100 and 125 cm. He reported that water table level at 25 cm inhibited the germination in both plant canes and ratoons, and caused reductions in the number of stalks, growth and production of cane and sugar. Water table level at 50 cm gave intermediate results, and differences between the treatments at 75, 100 and 125 cm were not obtained.

Perez and Allison[3] studied, in lysimeters as well as under field conditions, the

effect of water table depth on the production of seven sugarcane cultivars. Production of some cultivars was greater when water table levels are kept deep, while cultivars PR 1028 and PR 1141 were very tolerant to superficial water tables.

Considering the effect of water table level on sugarcane ripening Yang[8] recommended irrigation and deep drainage of cane cultivated fields to promote good ripening.

In Peru, Bazan and Sevilla[1] conducted an experiment in deep containers to study the effect of the static water table on the germination, growth and production of cultivar H32-8560. According to the results, the levels of 60 and 80 cm depth showed better conditions for germination and growth. At the same time, highly significant differences were found between the treatments and check (150 cm depth) with regard to yield in both weight and recoverable sugar (kg/container) standing out the treatment at 60 cm.

On the other hand, Risseeuw[5] concluded that the incidence of high water table levels on the production of cane and sugar is of little importance unless it bears high soil salinities.

The present research work was conducted with the objective of knowing the effect of various time persisting water table levels on cane production.

MATERIALS AND METHODS

The experiment was conducted in the fields of Plan Sausal I of the Cooperativa Agraria de Produccion (CAP) Casa Grande Ltda. No. 32, and Chiquitoy Viejo 1º and Chiquitoy 2º of CAP Cartavio Ltda. No. 39, located at the lower part of the Chicama River Valley, Peru.

The soils in Plan Sausal I and Chiquitoy 2º fields vary from medium texture (loam, silty loam) at surface (00-90 cm), to moderately coarse texture (fine sandy loam) at depth (90-210 cm). At 210 cm depth, soil texture was moderately coarse (sandy loam, fine sandy loam) in the Chiquitoy Viejo 1º field. The salinity values were within the permissible range for sugarcane cultivation ($EC_e < 4$ mmhos/cm) in the Plan Sausal I field, while in the Chiquitoy Viejo 1º and Chiquitoy 2º fields, salinity values varied, being possible to classify the soils from normal ($EC_e < 4$ mmhos/cm) to saline ($EC_e > 4$ mmhos/cm) according to the classification given by Richards[4] (Table 1).

The work was carried out considering each "cuartel" (split field) as a harvest unit, installing an observation tube per "cuartel" to control the water table level. The measurements of the water table levels were made at seven days interval, during two consecutive sugar crops (first and second harvest). Some periodic controls were performed to evaluate the growth of crops. Cane quality was determined by means of ripening samplings starting from 14 months of age. Moreover, a

production sampling in burned cane was made (mean age of harvest, 20 months).

TABLE 1. Results of soil physical analysis

Field	Mean Arany Number 00-90 cm K_A	Mean electrical conductivity of saturation (00-90 cm) CE_e (mmhos/cm)
Plan Sausal I	50	2.55
Chiquitoy Viejo 1°	44	4.34
Chiquitoy 2°	52	4.25

TABLE 2. Variation per depth of the model parameters

Depth (cm)	Parameters a	b	c	d	f
60	0.776774	0.223226	0.0215	7.50	2.55
80	0.783226	0.216774	0.0178	6.50	2.44
100	0.789677	0.210323	0.0141	5.50	2.33
120	0.796129	0.203871	0.0104	4.50	2.22
140	0.802581	0.197419	0.0067	3.50	2.11
160	0.809032	0.190968	0.0030	2.50	2.00

TABLE 3. Coefficients of correlation for the different water table levels

Comparison	r
Days over 60 cm vs. cane (t/ha)	-0.60*
Days over 80 cm vs. cane (t/ha)	-0.65*
Days over 100 cm vs. cane (t/ha)	-0.65*
Days over 120 cm vs. cane (t/ha)	-0.69*
Days over 140 cm vs. cane (t/ha)	-0.72**
Days over 160 cm vs. cane (t/ha)	-0.65*

* *Significant*

** *Highly significant*

The evaluation of the effect of water table level was executed from the criterion of relating the production to the persistence of water table levels at depths of 60, 80, 100, 120, 140 and 160 cm, such a criterion similar to that proposed by Sieben (in Wesseling[6]). Corresponding mathematical models were formulated.

RESULTS AND DISCUSSION

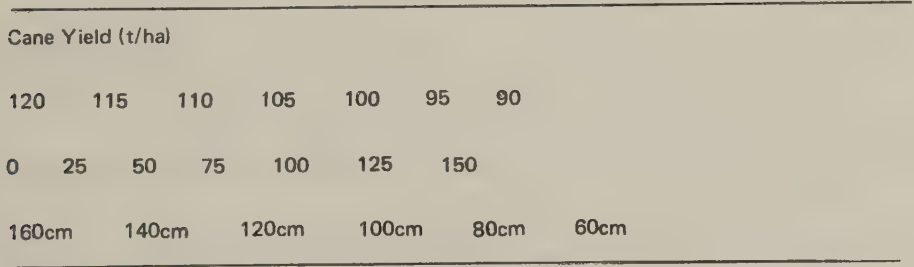
Because of the inconsistency of obtained data, it was decided to consider only the data from PI and Sausal I field.

The mathematical model which expresses the relation between the water table levels at depths of 60, 80, 100, 120, 140 and 160 cm, and the cane production (t/ha) is as follows:

$$Y = 116.25 \left(a - \frac{b}{1 + c \left(\frac{x - d}{3} \right) f} \right)$$

Where: Y is the cane production in t/ha, X is the number of days of the water table level persistence. The values of the parameters a, b, c, d and f vary with the depth and are given in Table 2.

FIGURE 1. Cane yield as a function of the ground water persistence at determined water table level



Days of the water table over determined level.

The values of the coefficient of correlation in Table 3 were obtained using the established models. It can be observed that cane production is negatively correlated to the number of days of the water table levels persistence over the determined levels. Significant correlations were found for the models of the water table levels at 60, 80, 100, 120 and 160 cm, and a highly significant correlation for the corresponding model to the water table levels at 140 cm depth.

It can be seen from Fig. 1 that cane production in t/ha decreases according to the number of days of the water table persistence over selected level increases. This decrease is quite great at the beginning, especially for cases where the water

table levels were at 60, 80 and 100 cm. Afterwards, the decrease of production became slow with time until it reached a minimum level of production, which was lower as the position of the water table level remained on the superficial levels.

The maximum yields in cane were obtained when water table levels were kept below 140 cm depth.

The results found using the Sieben's method (in Wesseling[6]), likewise indicate that continuous water table levels have a negative effect on summer and winter crops. The application of this methodology to evaluate the effect of the water table levels on sugarcane production, allows the definition of the dynamic drainage design criteria.

CONCLUSIONS

Negative correlations were found between cane production and the number of days of the water table persistence at determined levels.

There were significant correlations between cane production and the water table levels persisting at depths of 60, 80, 100, 120 and 160 cm. The correlation was highly significant for water table levels persisting at 140 cm depth.

Maximum cane yields were obtained when water table levels were kept below 140 cm depth.

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EFECTO DEL NIVEL FREATICO EN LA PRODUCCION DE CAÑA DE AZUCAR

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RESUMEN

En campos de las Cooperativas Casa Grande y Cartavio, valle Chicama, Costa Norte del Peru, se realizo una serie de experimentos, para evaluar el efecto de los niveles freaticos dinamicos en la produccion de caña de azucar.

La evaluacion se realizo a partir del criterio de relacionar la produccion de caña con la persistencia de niveles freaticos sobre los niveles de 60, 80, 100, 120, 140 y 160 cm. Se encontraron correlaciones significativas entre la produccion de caña (t/ha) con la persistencia de los niveles freaticos sobre los niveles de 60, 80, 100, 120 y 160 cm de profundidad y una correlacion altamente significativa con le persistencia de los niveles freaticos sobre el nivel de 140 cm de profundidad.

Los maximos rendimientos en caña se obtienen cuando los niveles freaticos se mantienen por debajo de 140 cm de profundidad.

MODELS OF ADVANCE AND INFILTRATION IN SUGARCANE IRRIGATION

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ABSTRACT

Irrigation studies were carried out in the Agrarian Cooperatives of Production at the Peruvian northern coast, with the purpose of finding advance prediction models and infiltration of the irrigation water along the furrows.

The irrigation volume, age of cane, slope of furrow bottom, and soil moisture level before testing were considered as variables in the study of the advance model, which was performed independently in three fields of different texture, and thus being the final model found only in the function of the first two variables.

With regard to the study of the infiltration model, only the texture was considered as the variable, by reason of which three textural ranges: sandy, loamy, and clay were selected and finding a specific model for each.

The results found in this work are of enough confidence by their high determination coefficient and statistical significance.

INTRODUCTION

The accomplishment of an irrigation project depends on the good use of irrigation water. The irrigation practices render into profits when these are reasonably managed, otherwise, drainage and/or salinity problems with their subsequent negative effects on production may result.

For didactic purposes, irrigation is divided into two stages. Firstly, the advance, which should be made with a non-erosional maximum volume in order to obtain a minimum difference in time between the head and the end of furrow. Thus, resulting into an even distribution of the wetting profile. Secondly, the irrigation itself, which should be made with a less volume than that of the advance, so that the surface runoff water be a minimum, ending when wetting of the rooting zone is obtained, thus giving rise to recession. The advance plays a very

important role in the efficiency level (Hoekstra and Silva[2]).

The length covered by the water volume flowing in the furrow surface, follows a potential function (Velasco[8]), whose paramenters depend on both the furrow hydraulic conditions and the infiltration characteristics of soil (Hoekstra and Silva [2] , and Vasquez *et al*[6]). Lewis and Milne (In Vasquez and Cruzado[5]) express by a mathematical function the combined action of the surface water advance and the infiltration. Fok and Bishop[1], performed an analysis of water flow during irrigation considering the infiltration velocity and the profile of water on the surface.

A methodology used for field conditions which permits to quantify the infiltration rate is that proposed by Funkel and Nir (In Hoekstra and Silva[2]); the same which was used in the present work, whose objective was the determination of mathematical models which may allow to predict the advance and infiltration of water in sugarcane irrigation.

MATERIALS AND METHODS

This research work comprises two different studies, namely the models of advance and infiltration of the irrigation water.

The advanced model study was carried out in the fields Medanos 1-B, Nepen 1-B and Nazareno 12, of the Cooperativa Agraria de Produccion (CAP) Cartavio cultivated with plant cane. The tests were initiated in March 1977 and started from 40 days of crop age to approximately 9 months of cane age.

The variables considered under study were soil texture, irrigation volume, soil moisture level before each test, slope of furrow bottom, age of crop. The fields were selected by their texture, performing in each of them the following labors: delimitation of two plots of twenty furrows each, then each plot divided into four groups of five furrows each with one water entrance ditch per group, sampling for textural analysis, measurement of the slope of furrow bottom, tests of advance in each entrance ditch with constant volumes per furrow of two, four, six and seven liters per second; being considered for the statistical analysis the results of the three central furrows of each group; repeating every test at intervals within the range from 42 to 90 days.

The infiltration model study was performed in fields selected by their texture, absence of the water table, and representativeness, in the Cooperatives Paramonga, Casa Grande, Cartavio, Laredo, Pucala, Pomalca, Tuman and Cayalti, either with plant canes of first ratoons, and younger than 6 months of age, thus obtaining a total of 24 tests. The variables considered in the study were the irrigation volume, soil texture and length of furrow.

TABLE 1. Results of field tests. Constant volume per furrow (l/s) time of advance (min), age of crop (days), for three fields of different texture.

Constant volume per furrow (l/s)	Medanos 1-B *K_A = 28.3 **L = 85 m					Nepen 1-B *K_A = 46.7 **L = 115 m					Nazareno 12 *K_A = 64.5 **L = 105 m			
	Age (days)													
	40	82	119	207	257	45	80	139	206	234	92	137	190	232
2	13.8***	26.3	22.5	23.7	28.0	14.5	19.5	22.0	31.0	32.0	31.5	29.5	32.5	62.0
4	12.5	20.8	21.0	21.0	22.0	14.5	18.0	19.5	30.2	28.5	18.4	21.5	20.3	35.5
6	9.2	16.5	15.5	18.0	18.5	12.7	15.5	18.0	24.7	25.0	16.2	17.0	16.3	28.5
7	8.0	13.7	14.5	15.0	17.0	12.0	14.2	17.5	14.0	23.0	15.3	15.0	15.6	25.5

*K_A : *Moisture percentage of soil saturated paste (Arany number)*
**L : *Length of furrow up to where the advance was controlled (m)*
*** : *Time taken by water to cover the length L (min)*

Measurements were made in the three central furrows of each group, according to the methodology proposed by Finkel and Nir (In Hekstra and Silva[2]) for which it is required to know in each time unit the water balance in the furrow.

$$Inf = Vol - (Sal + Rell)$$

where:

Inf	:	Total water infiltrated
Vol	:	Total inflow water into the furrow
Sal	:	Total water that went out of furrow
Rell	:	The amount of water stored above the ground surface

RESULTS AND DISCUSSION

A summary with the results of the advance tests at different ages and with different volumes obtained in each of the fields is shown in Table 1.

Table 2 shows the results of the regression analysis for the model obtained from processing field data according to:

$$X = a\ E^b\ Q^c\ T^r$$

where,

X	:	Distance covered by water (m)
E	:	Age of cane (days)
Q	:	Irrigation volume per furrow (l/s)
T	:	Time for water to cover the distance X (min)
a,b,c,r	:	Constants

TABLE 2. Results of the regression analysis for the advance model

Field Parameter	Médanos 1-B	Nepén 1-B	Nazareno 12
a	10.45	37.07	26.56
b	–0.2292	–0.3436	–0.3669
c	0.3944	0.0428	0.4132
r	0.9524	0.9117	0.8373
R^2	0.96	0.97	0.94
Sig.	xx	xx	xx

Sig. : Statistical significant at 99%

The results of field tests carried out for determining the infiltration model are shown in Table 3.

TABLE 3. Results of the infiltration tests

Field	Basic data			Result of test			
	L_s (m)	K_A^{30}	K_A^{90}	$\bar{Q}$ (l/s)	T_r (min)	a	b
Carreteria Alta	120	44	45	3.5	120	8.2	0.34
Natasha Alta	119	37	33	3.9	95	4.4	0.65
Monjas 1 A	115	55	58	3.2	190	3.3	0.55
Porvenir	78	41	37	2.2	136	9.0	0.47
Louisiana II	120	60	60	3.2	260	0.8	0.88
Jiron A	125	43	35	3.4	120	1.8	0.41
Pucuche B	120	46	43	3.0	150	8.1	0.52
Jiron B	119	43	35	3.4	70	5.9	0.63
Medanos 1-B	110	32	28	4.0	65	4.1	0.77
Nepen 1-B	120	45	47	4.0	110	7.8	0.50
Pampas 12	161	44	45	4.6	180	3.0	0.68
Pampas 13	135	50	50	3.5	368	6.6	0.57
Chuin 12	129	40	38	2.1	154	1.7	0.72
Tutumal	152	49	47	4.4	140	4.3	0.63
Pampas 15	150	65	67	5.3	159	2.2	0.75
25 de Agosto	141	56	48	3.8	159	13.6	0.48
San Jose A	111	59	47	3.8	173	10.5	0.51
Nazareno 12	120	64	60	4.0	150	4.2	0.53
El Examen	71	33	33	3.1	40	2.9	0.76
Cafetal	95	35	32	4.2	39	3.0	0.75
Huancay	113	32	31	8.1	40	4.5	0.82
San Isidro	134	46	42	3.9	67	7.5	0.55
Vista Florida	75	51	46	2.6	88	6.2	0.68
Lavalle	117	56	52	5.9	32	7.5	0.63

where:

L_s : Length of furrow (m)
K_A^{30} : Arany number of depth 0—30 cm
K_A^{90} : Arany number of depth 0—90 cm
$\bar{Q}$: Average of irrigation volume per furrow (1/s)
T_r : Time duration of the infiltration test (min)
a, b : Parameters of potential model of infiltration: $I_{ac} = aT_o^b$

The average slope of furrow bottom is between the range of 3 to 5%

The results of the regression analysis to find a function which quantifies the infiltration rate accumulated according to soil texture is presented in Table 4.

TABLE 4. Result of the statistical analysis for the accumulate infiltration models per textural range

Textural range	Equation of accumulate infiltration	R^2	Sig.
$K_A < 40$	$I_{ac} = 4.3 \times T_O^{0.75}$	0.78	xx
$40 < K_A < 55$	$I_{ac} = 8.2 \times T_O^{0.51}$	0.82	xx
$K_A > 55$	$I_{ac} = 4.1 \times T_O^{0.55}$	0.77	xx

where,

I_{ac} : Accumulate infiltration water depth (mm)
T_O : Opportunity time (min).

DISCUSSION

It can be observed from Table 1 that there was a difference in the time of advance for volumes from 2 to 7 liters per second per furrow. This difference increased as the age of cane increased. Likewise, the time of advance increased as age of cane increased because of the increase of the hydraulic resistance caused by the greater number of stalks, presence of dry leaves and lodged stalks along the furrows. This agrees with results obtained by Vasquez, *et al*[6].

From a graphic analysis and according to the results of the regression analysis of the advance model which are shown in Table 2, the more important variables were the age of crop and the irrigation volume. Somewhat important in the general model were the slope of furrow bottom and the soil moisture degree before the test was made. These confirms the results of Neuman[3].

With regards to the results of the prediction model for the accumulate infiltration presented in Table 4, the equations obtained had good determination coefficient and were highly significant. It was observed that there was no logical correspondence, since for the coarse texture range the coefficient (volume of infiltrated water) in the first time unit was less than for the medium-texture range. Likewise, the exponent (rate of basic infiltration) found for a fine texture soil was greater than that for a medium-texture soil. Theoretically, the contrary was true, but because the measurement were taken under practical field conditions, clods were along the furrows little counter slopes, as well as the moisture degree of soils were not uniform. Moreover, in the fine textured group, there was not enough time for measurement in each test, consequently, it was not possible to obtain the basic infiltration.

CONCLUSIONS

The irrigation volume during the advance was around 7 liters per second per furrow.

The equations found for the prediction of water advance in the furrow, are of enough confidence and valid only for plant canes younger than 12 months of age.

The volume per furrow and per time of irrigation are two of the factors of greater importance in the irrigation efficiencies.

The equations found for the prediction of the accumulate infiltration volume, are of enough confidence and applicable to the sugarcane irrigation practices in the Peruvian coast.

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MODELO DE PREDICCION DE AVANCE E INFILTRACION EN EL RIEGO DE CAÑA DE AZUCAR

W. Silva, A. Vasquez, E. Paz-Vergara y A. Hoekstra

RESUMEN

En las Cooperativas Agrarias de Produccion (CAPs) de la Costa Norte del Peru se llevo a cabo estudios de riego con el fin de establecer pronostico de progreso e infiltracion de agua de riego a lo largo de los surcos.

El volumen de riego, edad de la caña, inclinacion del fondo del surco y el nivel de humedad del terreno antes de llevarse a cabo las pruebas, fueron considerados como variables para el estudio del modelo de progreso. Este estudio se llevo a cabo independientemente en tres campos de diferentes texturas siendo asi el modelo final el unico en funcion de las primeras dos variables.

Respecto al estudio del modelo de infiltracion se seleccionaron tres texturas diferentes: arenosa, margosa y arcillosa, y solamente la textura fue considerada como variable, y se creó un modelo especifico para cada una.

Los resultados obtenidos con este estudio son suficientemente confiables por su alta coeficiencia y significado estadistico.

SUGARCANE SYSTEMS SYNCHRONIZATION OPPORTUNITIES AND PRODUCTION INPUT MODELS

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ABSTRACT

A sugar milling district consisting of a milling facility and an area producing cane in Central Punjab, Pakistan was selected to develop descriptive statistics of yield models and mill performance models as inputs to a larger management optimization model for the scheduling of milling operations and harvesting of the crop. The study indicated that the area planted and harvested was responsive to the mill performance in terms of transportation, weighing and pricing at the purchase centers. The harvests following a flood in the monsoon season had exceptionally good cane yields, whereas drought in the monsoon season results in markedly lower cane yields in the following harvest season. Linear and logarithmic regressions were used for yield modelling using number of plowings, number of irrigations, amount of fertilizer, number of manual hoeings, number of animal hoeings, ground water table depth, age of crop at harvest and month of harvest as inputs. The linear and logarithmic models used explained 33% to 68% variability in the yield and the results include only those inputs which were significant at 99% level of probability. The yield of sugarcane crop gives comparatively better fit as compared with logarithmic regression. The mill performance models for cane crushed and defined sugar bagged were developed by linear regression while the sugar recovery model was developed by quadratic regression.

INTRODUCTION

Sugarcane systems in Pakistan

A particular cane supply management system was chosen for study in Pun-

jab. This sugarcane district is considered representative of many sugar cane systems in the country. The primary responsibility of the cane management department is to assume steady supply of sugarcane over time for the mill. The department achieves the goal by:

1) *Survey system.* It may also be referred as the area inventory. There are two periods in which the surveys are conducted. The first period is from June-July and the second period is from February to the first week of March.

The object of the first survey is to determine the total acreage of sugarcane in the mill zone area (MZA) for both sown and ratoon crop.

Hired labor is used for this purpose. Each surveyor is allocated three villages and he has to conduct the survey at the rate of 120 hectares/day. The first survey will thereby yield the total tonnage of sugarcane obtainable from MZA (using an assumption of 37 tons/hectare). This will enable the mill schedule to accept cane from free area outside the MZA.

The purpose of the second survey is to determine the rest of acreage of sugar cane from MZA, which has been previously estimated by the first survey. Hence this survey will help to allocate more indents to those farmers whose production is higher than 37 tons/hectare.

2) *Indent Allocation System.* This indent allocation system was resorted to because 1) the crushing capacity of the mill is limited (daily), 2) the mill has limited capacity of yard/storage, and 3) sugar content decreases after 72 hours of harvest. Therefore the mill has to schedule the acceptance of sugarcane from the growers in order to have feasibility for the mill and for the growers by indent allocation system. The indent allocation system is as follows:

a) Crushing capacity for the mill is determined (for Sample Sugar Mill, it is 2000 MT/day).

b) Total acreage of sugarcane in mill zone area is determined (16,000 hectares for sugar mill).

Depending on the individual holding size, the permit interval is determined in the following way. If a farmer has 0.8 hectare of sugarcane, then the proportion of his area to the total area in the mill zone is:

$$\text{Proportion (PA)} = \frac{0.8}{16.000} = 5 \times 10^{-5}$$

The rate at which he can supply cane to the mill (R_{cs}) = Crushing capacity of mill.

Proportionate area of the farmer (PA):

$$= 2000 \times 5 \times 10^{-5} = 10{,}000 \times 10^{-5} = 0.1 \text{ MT/day}$$

The means of transportation that the individual possesses determines the Rate of Indent allocation (IR).

$$IR = \frac{\text{Capacity of the mean of transportation}}{\text{the rate of supply (Rcs)}}$$

If the farmer has a transportation mean with a capacity of 1 MT, then the Indent Interval Rate (IIR) is:

$$IIR = \frac{1.0}{0.1} = 10 \text{ days}$$

Possibilities for Improvement in the System

The major defect in the present indent allocation system is that the ratoon crop is treated in the same fashion as the sown crop. The ratoon crop matures earlier when compared with sown crop. The advantage of early maturity of ratoon is therefore not availed by the mill. Hence there should be a management policy to treat the ratoon independently from sown crop in order to obtain the comparative economic advantages to the grower and to the mill. It is therefore recommended that ratoon should be accepted earlier based on field information. It is proposed that more detailed and frequent surveys be made to make such distinction.

The maturity of the crop is also affected by the depth of water table. Hence accordingly the indents should be allocated to those areas where the sugar cane matures earlier due to the lack of effect of high water table. As such as groundwater contour map should be developed and used as a basis for allocation of indents.

The frost and rainfall are microclimatic elements, information on which if collected at one center location (city) does not apply to all the countryside. Therefore it is recommended to install non-recording raingauge and thermometer at each purchasing station that can be an aid and a good tool for the cane supply department to allocate the indents based on severity of frost and rainfall encountered.

MATERIALS AND METHODS

Production Modelling

Stepwise multiple regression was used for production modelling. The method of stepwise multiple regression is by successively adding variables into regression equation. The variable to be added at any stage is the one which makes the greatest improvement in the goodness of fit or the one which causes greatest variance reduction. At each stage after the variables have been added into the regression, a test for significance of variables already in the regression is also made. If the var-

iance contribution of a variable in regression is insignificant, this variable is removed before adding another variable (Heady and Dillon[4]).

The important property of stepwise multiple regression is based on the fact that a variable may be indicated to be significant in early stage and thus enter the equation. After several other variables are added to the regression equation, the initial variable may be indicated to be insignificant. The insignificant variable will be removed from the regression equation before adding an additional variable. Therefore only significant variables are included in final regression equation (Early[2,3]).

Data Description for Production Models

The area selected for this study has a large acreage under sugarcane cultivation and the farmers in this area had been growing this crop for many years. Since sugarcane requires a long growth period of time in the field, the study of the current crop was not possible, hence the crop of the preceeding season was selected for the study. The collection of the data included the entire period from planting until disposal of the crop. A questionnaire schedule was prepared in consultation with the cane manager of the mill. Since the time available was very short, one farmer was selected randomly from each village. The questionnaire was protested in the area before it was finally accepted. Each farmer was visited separately along with the research officer of the sugar mill to get the desired information. The farmers answered the questions from their memory and results were meticulously recorded in the questionnaire. The survey involved about 30 man-days interview efforts, (Ayub[1]).

The information sought related to all farming operations of the sugarcane crop, its cost, its production, returns, hazards and inputs. Besides those types of data, information was also collected which indicated the attitude of the farmer about certain policies and reveal unscrupulous practices surrounding the sugarcane enterprise.

An extensive survey was also conducted throughout the whole mill zone area for the determination of ground water table because this information was not available from the farmer's interview. The depth of water of persian wells or open wells for at least two sources (either open or persian well) located either in the field or near the fields were selected from each village. The height of the edge of the wall above field was subtracted from the measured depth in order to obtain the ground water table for field conditions. In few villages where there was no source available, the blacksmith who installs the hand pump was interviewed to determine the ground water table depth. The survey involved about 22 man-days (Ayub[1]).

The data was recorded in the following format: the number of plowing, plankings and hoeings, kilograms/hectare of fertilizers, number of bullock cart, volumes of manure, and the age of crop at harvest in days. Since the fertilizers and the manure were nutritive elements, these nutritive contents were accumula-

ted in order to find out the total input values. Standard conversions were used, with a bullock cart of manure weighing 0.75 ton assumed to have 3.5 kg of nitrogen, 2.5 kg of phosphorus and 5.0 kg of potassium.

Mill Performance Model

The mill performance models were developed by using linear and polynomial regression. The performance evaluation data like cane crushed and sugar bagged, and recovery was obtained from sugar mill located in the district. A six-year record from October 1969 to April 1975 was used in the development of mill performance model. The description of the data follows:

1) Cane crushed as observed from 07:00 am to 07:00 am the following day and recorded in tons of cane crushed/day.

2) Sugar bagged, as the amount of white sugar refined in tons/day.

3) The ratio of the sucrose content to the total juice, referred to as recovery.

RESULTS AND DISCUSSION

Description of the Study Area

The area chosen in this study is in district Faisalabad, Punjab, Pakistan. The district lies between east latitudes 73° and 74° and north latitudes 30° and 31.15°

The climate of the district is on the whole hot and dry. The temperature varies considerably from season to season. The mean maximum temperature in summer is 36°C and minimum 24°C while the winter mean temperatures are 24°C and 8°C. The highest temperature in the hot weather may touch the 49°C mark and the minimum 21°C. In winter the temperature falls considerably and in January it sometimes goes below the freezing point.

Mill Zone Area and Free Zone Area

The sugar mill in the district of Faisalabad, Punjab, Pakistan was established in 1960 with the aim to overcome the sugar shortage in the country. In order to have the assurance of supply of fresh raw material for the mill, the authorities of the mill requested the government to provide the legislative support for the regular supply of raw material. Consequently in 1962, the government approved a statute by which 124 villages in the vicinity of the mill were declared as mill zone areas. It was further stated that the farmers in the mill zone area are bound to supply the sugarcane to the mill, Khandsari and gur making is prohibited, 20% of the crop grown by the farmers is for domestic purposes, and the mill is responsible for all the crop grown in the area.

The total acreage under sugarcane crop in 124 villages in 1969-70 season was approximately 14,000 hectares with an average supply of 1000 to 1500 tons per day. In 1975-76 season it was only 10,500 hectares. In order to compensate for the possible shortcoming of raw material, the mill was also permitted to accept the sugarcane from the other areas not included in the mill zone. The areas which supply sugarcane to the mill from outside the declared mill zone are termed as free zones. Fig 1 shows the villages of the zone area and the villages in the surrounding area of Faisalabad.

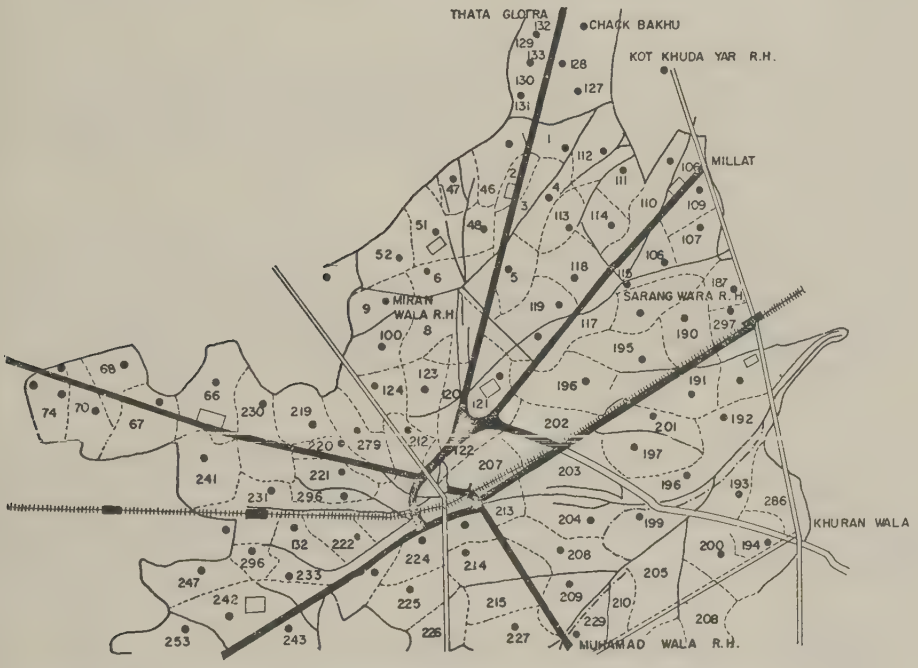

FIGURE 1. A map indicating location of mill and purchase centers

Sugarcane is a 10-18 month crop. It competes with other cash and food crops and the acreage of cultivation of the sugarcane crop to a greater extent depends on the relative market price of other competing crops.

There was a gradual decrease of 9% and 12%, respectively, from the season 1969-1970 to 1971-1972, due to farmers' dissatisfaction of excessive cane crop in 1969-1970, and the mill's inability to crush the entire supply of that year. The farmers reported unharvested standing cane after July and burned canes in the field which were complete losses. After 1972-1973 season the cropped area again increased by 12% and remained stable through 1974-1975 season. The 1975-1976 season saw another decline of 16%. The reasons for the latter fluctuations are not known.

Purchase Centers

Communication, transport and marketing facilities are the main agricultural support infrastructure and play an important role in the agricultural development of a particular region. In this context, the mill zone area does not have adequate facilities in terms of paved roads by which the farmers could market their products at a lesser cost. Only some earthen roads link different villages with each other with the mill gate, and the condition of these roads is very bad. Thus, the movement of farm supplies and produce is somewhat difficult and a time-consuming process.

Considering the difficulties which the farmers face and to meet the requirements of sugarcane quality, the mill planned to establish the purchasing (transhipment) centers in its mill zone area. During the season 1972-1973, six purchasing centers were established, as shown in Fig. 1.

Each purchase center is operated under the supervision of a field man who is an employee of the mill. Each purchasing center is inspected by the field officer daily. On the bases of the inventory of each purchase center, transportation is allocated. The price offered at the purchase centers is the price at the factory gate less transportation and service charges.

The growers selling their product to the purchase centers are not satisfied with the system of evaluation of the product especially with the weighing of the cane. Another source of farmers' dissatisfaction is the level of charges assessed by the mill for transportation and services. The purchase centers operate during the period of October through April.

Farmers and their Distribution by Purchase Center

About 10,000 farmers in the mill zone area grow the sugarcane crop, the yields of which are generally low by world standards. During the year 1973-1974, more than 1600 farmers were in the yield category of less than 13.6 tons/ha (category No. 1) and only 100 farmers have their production in the yield category No. 8, which is greater than 54.4 tons/ha (Fig. 2). This was the crop year following the flood of August, 1972 and indicated generally high yield. In the year 1974-1975, the number of farmers in the yield category No. 1 was increased by 256% No. 8 was decreased by 13%. The season 1975-1976 was quite impressive for crop production. The crop production data shows a decrease of 59% in the yield category No. 1 and an increase of 37% in the yield category No. 2 and 3 (13.6-22.7 tons/ha) and (22.7-27.2 tons/ha) respectively, again attributed to the year following a flood. An increase of 30% was also observed in the yield category No. 8.

The aggregate analysis of the production data for a period of three years

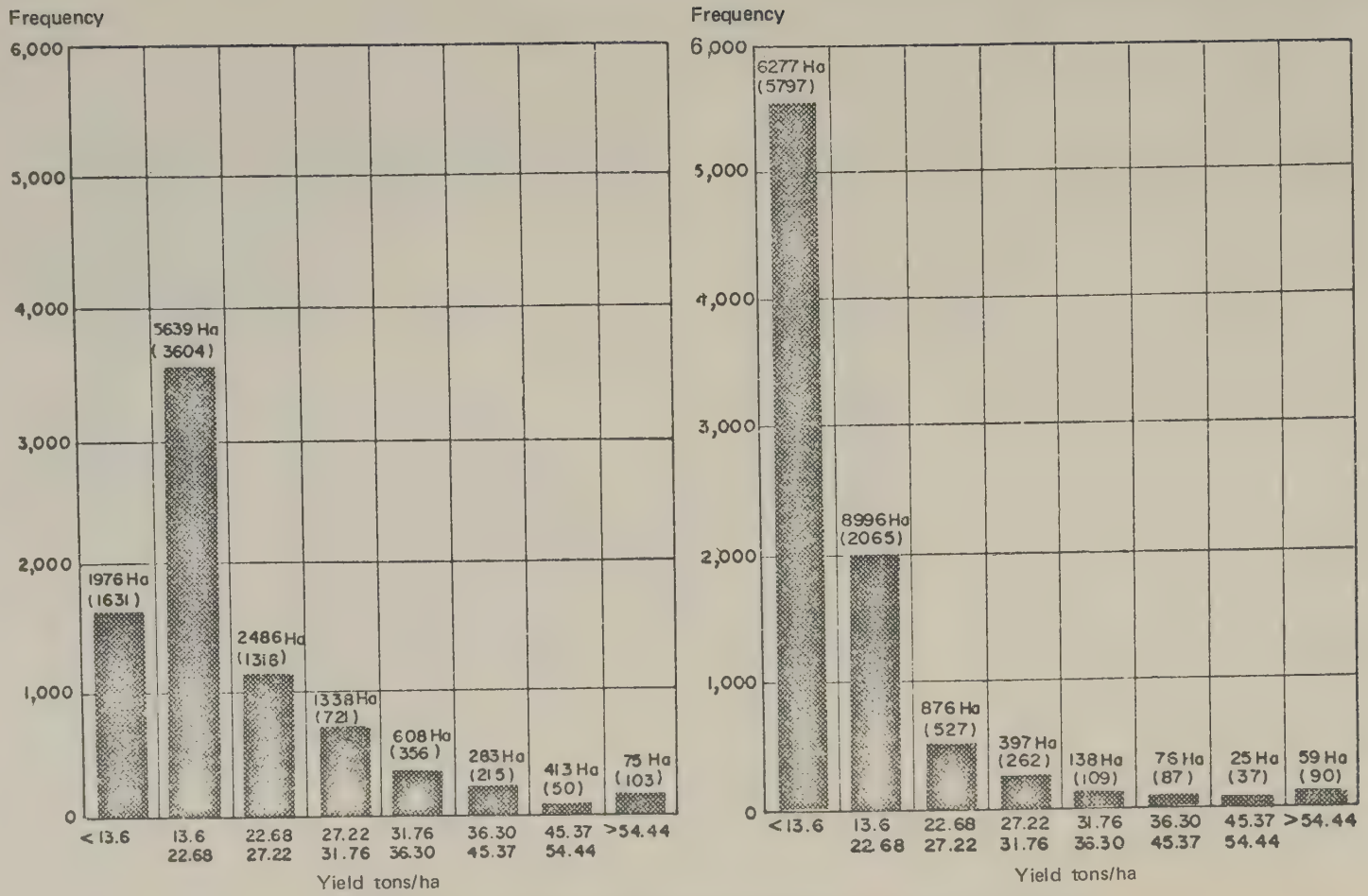

FIGURE 2a. Sugarcane yields of Pakistani farmers (1973 and 1974).

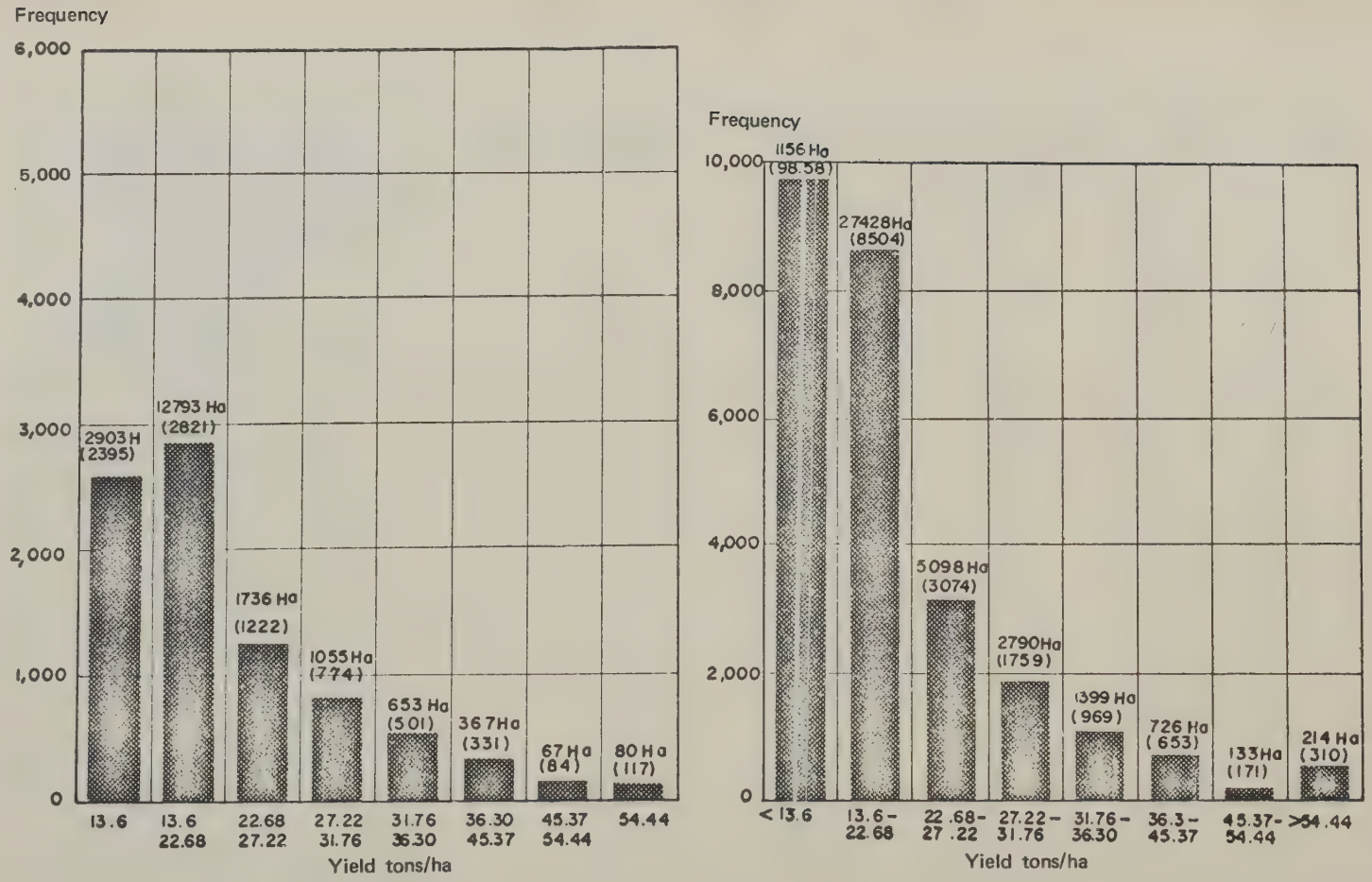

FIGURE 2b. Sugarcane yields of Pakistani farmers (1975 and 1976).

indicates that about 39% of the farmers have their yield in category No. 1; 34% in category 2; and 12% in yield category 8. For these three-year data, the maximum number of farmers growing sugarcane occurred in year 1974-1975 and equalled 8994. The average number of the growers in mill zone area is about 8,000.

The distribution of the farmers by purchase center show a positive trend of the farmers towards the use of purchase center facilities. The aggregate percentage distribution of the farmers who avail of the purchase facility increased from 32% in 1973-74 to 34% in 1974-75 and to 37% In 1975-76.

At present there are six purchase centers working in the zone area. Out of total 124 villages in the mill zone area only 34 have the facility of selling their sugarcane produce to the purchase centers, whereas the farmers in the remaining villages supply sugarcane at the mill gate.

Ground water Table

The ground water table plays an important role on the maturity, tonnage and rendement yield of the sugarcane. The information about the ground water table were obtained by conducting a survey in April 1977. It was observed that during the survey 18% of the mill zone area has a ground water table depth less than 1 m., 32% of the total area has 1-1.5 m, and rest of the area has greater than

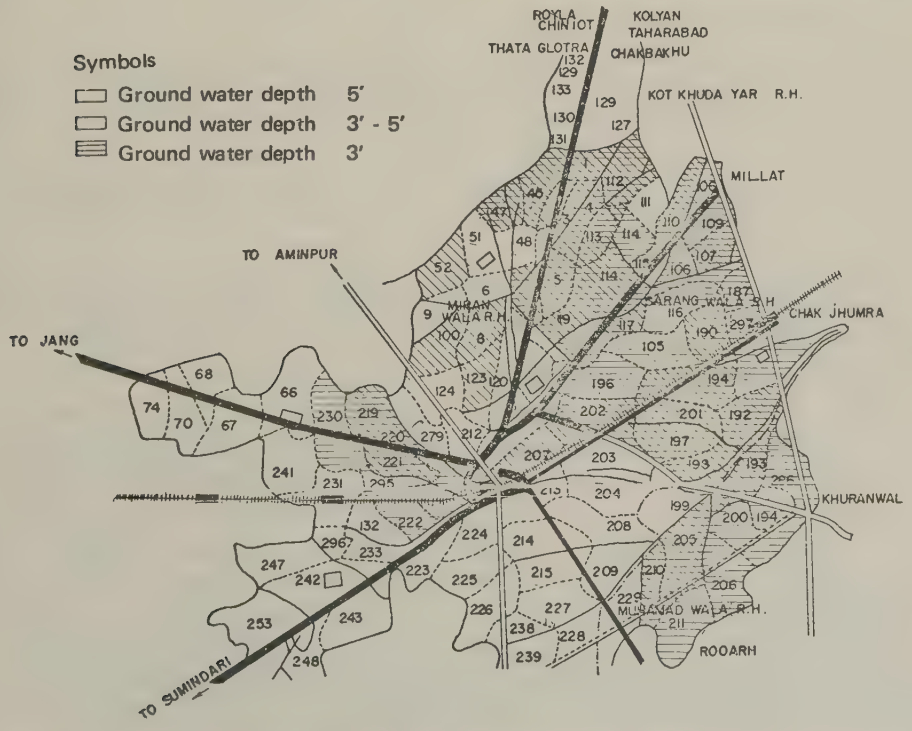

FIGURE 3. Ground water table map of cane supply area

1.5 m. (Fig. 3). The effect of the ground water table can be visualized in the succeeding section on the production modelling.

Yield Production Model

There are two different types of models used in this study. In Model 1 it is stipulated that the yield of sugar cane varies with the number of plowings, irrigations, amount of fertilizer, manure, number of weeding, groundwater table, age of the crop at the time of harvest, and the month of harvest. The effects of Model 1 are additive in nature. Model 2 is constructed in such a way that the effects are of multiplicative nature.

Model 1 Additive Function

The general linear function of this model is:

$$Y = b_o + b_1X_1 + b_2X_2 + b_3X_3 + \ldots\ldots\ldots + b_kX_k \ldots\ldots\ldots (1)$$

This type of model expresses the relation of crop production as the summation of the effects of various production factors. The models 1A for sown crop, 1B for intersown crop, 1C for ratoon crop based on additive functions are presented in Table 1.

Model 2 Multiplicative Functions

A disadvantage of Model 1 was that the predicted values of yield may be negative. To overcome this, a model of multilog functions was constructed as:

$$Y = b_0X_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}X_6^{b_6}X_7^{b_7}X_8^{b_8}X_9^{b_9}X_{10}^{b_{10}} \ldots (2$$

This model guaranteed that all the predicted values would certainly be positive, provided that constant b_0 is positive. The results are presented in Table 2.

Plant Cane Crop — additive model

All the ten independent variables entered are significant. However, the value of R^2 is not very impressive. The equation explains about 33% of the variation in the value of output per acre. It is noted that coefficients of all the variables have the expected sign with the exception of both animal and manual hoeing, and potassium. It would appear that hoeing have negative contribution towards the yield. But this need not be taken seriously since the standard error is much higher than the coefficient signifying that the probability is very low, that it is significantly different from zero. The variable Potassium, X_5 have negative sign, as the Punjab district soils are normally rich in potassium, and addition of potassium may have adverse effect.

Intersown Crop — additive model

All the ten independent variables are in the final regression equation. The value of R^2 is quite impressive: it explained 68% of the variation in the sugarcane yield. The variables X_1, X_6, X_7,X_{10}, have negative sign. It is further noted that the variables have very high standard error as compared with their regression coefficient indicating that the probability is very low and that they are significantly different from zero. The variable X_3, which is nitrogen, also has negative coefficient, indicating that application of nitrogen is toxic to the crop. This is true, since the intersown crop is normally sown together with leguminous crop in the same field which fixed the nitrogen into the soil. The variable X_2 irrigation has also shown an inverse relationship with the yield of the crop. As explained earlier, intersown crop is sown with some leguminous crop. Since there is very less plowing of the soil, the soil is normally compact and had lower capabilities to retain moisture. Because of the nature of intercropping, the farmers tend to over irrigate as often as weekly. Hence sign indicates possible yield depression. Moreover, the intersown crop has deep root zone due to competition with other crop thereby making use of ground water (X_8). The variable age (X_9) had negative sign, suggesting that the earlier the harvest of crop the better is the yield. The most contributing factor to yield production for intersown crop is phosphorus.

Ratoon Crop — additive model

The value $R^2 = .66$ is significant and explains the 66% of the total variation sugarcane production. The eight independent variables are in the final regression equation. Variable age (X_9) was not significant so it is not entered in regression equation. The regression coefficient of all independent variables have a positive sign except the variables X_2 and X_4, which are irrigation and phosphorus, respectively. The standard error of X_2 is much higher as compared with its regression coefficient signifying that the probabilitv is very low, that it is significantly different from zero. The phosphorus negative sign can be justified by the fact that the primary function of phosphorus is the development of the root system. However, since the root system of the ratoon crop have already been developed, the addition of phosphorus may be toxic to the crop. The major contributing factors to the ratoon crop's production are hoeing, ground water table, nitrogen and potassium as shown in Table 1.

Production Model Evaluation

The comparison of logarithmic and linear production models indicate that the value of R^2 for all the three cases i.e., plant crop, intersown crop and ratoon crops are better in linear regression equations. It is therefore concluded that independent variables in the regression equation gives better fit with linear relation than the logarithmic variables.

TABLE 1. Summarized results of step-wise linear regression analysis of sugarcane production

Sugarcane crop and yield equation	Intercept	Regression Co-efficients of Independent Variables										Multiple R	Multiple R^2	F	Se
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}				
Plant crop	128.40	3.61	0.70	0.81	0.62	-0.34	-51.58	-88.68	0.24	0.66	7.51	0.58	0.33	1.93	184.76
		(0.64)	(1.96)**	(1.79)**	(0.81)	(-0.42)	(-1.53)*	(-2.47)**	(0.49)	(0.86)	(0.91)				
Inter sown crop	1933.85	-188.81	-0.09	-0.99	2.75	2.84	-60.29	-131.05	0.66	-2.33	-28.65	0.83	0.68	2.34	138.99
	(-2.10	(-2.10)*	(-1.35)*	(-1.41) *	1.73) *	(0.87)	(-1.30) *	(-2.70)	(0.96)	(-2.03)*	(-2.43) ***				
Ratoon crop	431.96	–	-30.75	1.89	-0.67	7.04	13.29	71.73	2.78	–	9.89	0.81	0.66	1.67	122.01
			(-3.23)**	(1.59)*	(-0.96)	(2.24)**	(0.75)	(1.10)	(2.51)**		(0.72)				

NOTE: *F is variance ratio*
Se is standard error of estimate of the multiple linear regression equation
The coefficients within parenthesis are t values
*** *Significant at 0.01 level*
** *Significant at 0.05 level*
* *Significant at 0.10 level*

X_1 = *Plowing*
X_2 = *Irrigation*
X_3 = *Nitrogen*
X_4 = *Phosphorous*
X_5 = *Potassium*
X_6 = *Hoeing by animal labor*
X_7 = *Hoeing by manual*
X_8 = *Ground water depth*
X_9 = *Area at harvest*
X_{10} = *Month of harvest*

TABLE 2. Summarized results of logarithmic regression of sugar cane production.

Equation	Sugarcane yield	Inter-cept	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	Multiple R	Multiple R^2	F	Se
4.3.2.5	Plant crop	1.20	-0.035	0.25	0.36	0.021	-0.029	-0.31	-0.51	—	0.24	0.019	0.63	0.39	2.91	0.16
			(-0.26)	(1.68)**	(3.38)**	(0.42)	(-0.90)	(-2.08)**	(-3.12)**		(0.53)	(0.28)				
4.3.2.6	Inter sown crop	4.02	**(-0.52)**	-0.25	0.11	0.13	0.09	-0.08	(-0.17)	0.22	-0.49	-0.18	0.69	0.48	2.022	0 16
			(-1.24)	(-0.50)	(-0.55)	(1.56)*	(0.73)	(-0.36)	(-0.57)	(1.14)	(-0.45)	-1.55)				
4.3.2.7	Ratoon crop	1.68	—	-0.93	0.20	-0.03	0.13	**0.10**	—	0.26	**0.57**	-0.17	0.80	0.635	1.523	0.13
				(-3.06)**	(1.05)	(-0.69)*	(1.68)*	**(0.68)**		(1.59)*	**(0.94)**	-0.47)				

NOTE: *F is variance ratio*
Se is standard error of estimate of the multiple linear regression
*** *Significant at 0.01 level*
** *Significant at 0.05 level*
* *Significant at 0.10 level*

X_1 = *Plowing*
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X_7 = *Hoeing by manual*
X_8 = *Ground water depth*
X_9 = *Area at harvest*
X_{10} = *Month of harvest*

In the linear regression model, the final regression equation of the plant crop has a value of $R^2 = 0.33$ which explains only 33% of variation in the yield. As a greater percent of variation is not accounted by the model it is recommended that this model should not be used for prediction purposes. However, in the absence of any other model, this model can give some idea about the type of relationship of production functions and yield. The model should be calibrated before use.

The linear regression model of intersown crop explains 68% of total variation in the crop production. The values of R^2 and F are quite impressive, indicating that regression line has a good fit with actual observed data. This model can be used safely for the yield prediction in order to test alternative management policies. Since 32% of the total variation is not explained by this model, it is suggested to calibrate the model for any particular situation.

The ratoon crop model is also satisfactory since the 63% of total variation in the crop yield is explained by the independent variables present in the regression equation. It can be used for yield forecasting. However, it is suggested that the model should be calibrated before it is applied to a specific situation as the model fails to explain the remaining 37% variation of crop production.

In order to have an insight of the mill performance, the following three models were constructed.

(i) Sugar cane crushed versus time,

(ii) Sugar bagged versus time, and;

(iii) Recovery versus time.

The summarized results of the first three models are shown in Table 3. In these models, 'Y' is the dependent variable which is the accumulated value of sugarcane crushed and sugar bagged in successive 7-day intervals in models 1 and 2 and is the percentage recovery in model 3. The first two models (Figs. 4 and 5) show a linear relation with time, while model 3 has a parabolic relationship. The recovery is parabolic because when the mill starts processing the cane, the crop is still not fully mature due to rains of moonsoon, thereby continuing its growth and having high water and low sucrose content. As the sugar cane reaches maturity, the water content decreases and sucrose content increases, indicated by a gradual increase in the recovery (Fig. 6). The recovery attains its peak value during the period Jan-Feb. That period is followed by a high temperature, thus forcing the sucrose content to decrease causing the behaviour of recovery to be parabolic.

In model 4, it is stipulated that sugar bagged was measured as tons of sugar produced in 7-day intervals. 'Y' varies with the product of cane crushed and recovery. The model was subjected to simple regression analysis and the resultant

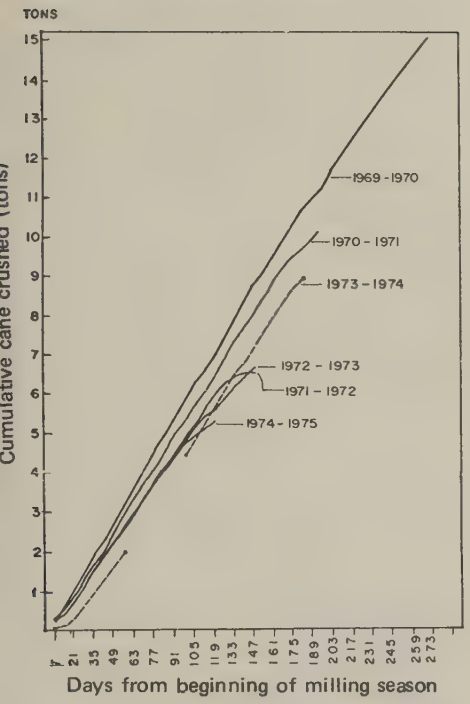

FIGURE 4. Mill performance as cumulative cane crushed (tons).

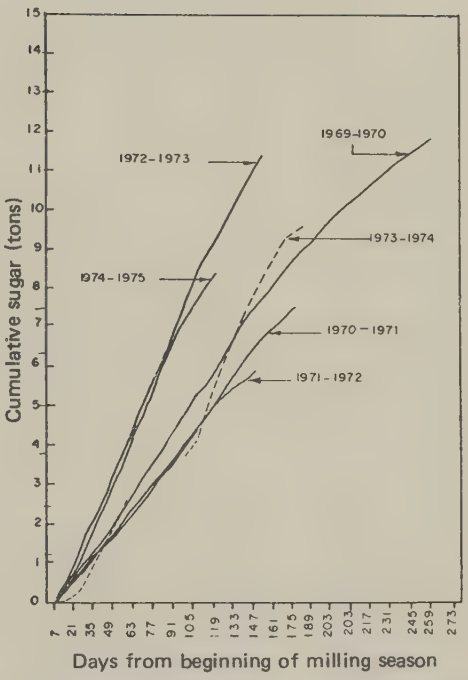

FIGURE 5. Mill performance as cumulative sugar produced (tons).

equation was:

$$Y = 1439.9 + 0.0035 \text{ (cane crushed) } x \text{ (recovery)}$$

$$(21.6) \qquad R^2 = 787, \quad F = 450.8$$

(value in the parenthesis is t-value)

The value of R^2 explains 79% of variation of the total variation in the sugar production. The value of independent variable is significant at 1% level of probability. The model fails to explain the 21% variation in the sugar yield.

Evaluation of Mill Performance Model

The models of sugarcane bagged, cane crushed and recovery can be used satisfactorily as outlined for the simulation of the sugarcane system.

The overall regression equation of cane crushed has the same $R^2 = 0.98$ which explains 98% variation in the tonnage of cane crushed. This model can be used with confidence for the prediction purposes.

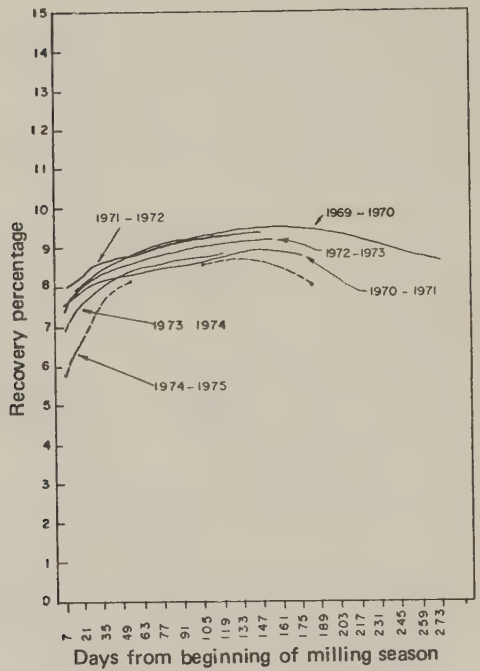

FIGURE 6. Recovery (percentage) as function of time

The values of R^2 for the model of sugar bagged and recovery are quite reasonable. As it is clear that some of the variations in the output of the cane crushed is not explained by that variable, therefore, it is suggested to calibrate them before they are used in any particular situation.

The model of sugar bagged versus product of cane crushed and recovery explains 79% variation in the sugar production. The model cannot be used satisfactorily as 21% of the variation is not explained by independent variables considered in the model for forecasting purpose. To be on the safe side, calibration of the model is required before use.

Limitations of Data

1. *Production Models*

   (a) Models are solely dependent upon the farmers memory.

   (b) Soil fertility, which is the most important factor of production has not been considered here.

   (c) Timeliness factor have not been taken into account.

   (d) The sample of farmers interviewed was only 0.8% of the total

TABLE 3. Regression equations for mill performance model

Year	Sugar bagged	Sugar cane crushed	Recovery
1969-70	$Y = 0.2171 + 0.06784\ t$ $R^2 = 0.9886, F = 3202.0$	$Y = 4.7749 + 2.07797\ t$ $R^2 = 0.9979, F = 7601.5$	$Y = 7.6040 + 0.0245\ t - 0.000078\ t^2$ $R^2 = 0.9854$
1970-71	$Y = -0.4051 + 0.0673\ t$ $R^2 = 0.9921, F = 2877.4$	$Y = -5.3669 + 2.0677\ t$ $R^2 = 0.9939, F = 3555.8$	$Y = 7.6568 + 0.0149\ t - 0.000046\ t^2$ $R^2 = 0.9698$
1971-72	$Y = -0.2901 + 0.0629\ t$ $R^2 = 0.9976, F = 7733.5$	$Y = 2.4086 + 1.7668\ t$ $R^2 = 0.9932, F = 2787.6$	$Y = 7.9849 + 0.0190\ t - 0.000067\ t^2$ $R^2 = 0.983$
1972-73	$Y = -0.5029 + 0.1173\ t$ $R^2 = 0.9972, F = 7105.6$	$Y = 0.1903 + 1.7321\ t$ $R^2 = 0.9965, F = 5735.7$	$Y = 7.5823 + 0.0236\ t - 0.000089\ t^2$ $R^2 = 0.9753$
1974-75	$Y = -0.8201 + 0.1153\ t$ $R^2 = 0.9957, F = 3465.8$	$Y = -5.3657 + 1.7835\ t$ $R^2 = 0.9946, F = 2755.3$	$Y = 7.3152 + 0.0271\ t - 0.000012\ t^2$ $R^2 = 0.9$
Overall	$Y = 0.5938 + 0.0699\ t$ $R^2 = 0.8466, F = 673.3$	$Y = -13.5949 + 2.0983\ t$ $R^2 = 0.9837, F = 7356.9$	$Y = 7.6812 + 0.0191\ t - 0.000057\ t^2$ $R^2 = 0.7837$

population.

2. *Mill Production Data*

   (a) Data was not available in stratified form.

   (b) No separate record of cane supply from mill zone area and free zone area was available.

   (c) Contribution of various varieties to the total cane supplied was not recorded.

   (d) Supply and quality of sugarcane from each purchase center was not recorded separately.

CONCLUSION

Yield Model

(a) Linear regression gives a better fit when compared with the logarithmic regression, but the advantage is slight.

(b) Irrigation and nitrogen are the major contributing factors towards the yield of the plant crop. Potassium need not be applied if better result is desired. Higher tonnage can be obtained by the late harvesting.

(c) Intersown crop is very sensitive to the moisture regime of the soil. Ground water is normally used by the crop, therefore, surface irrigation need not be so frequently applied. Due to competition with the intersown crop, earlier harvest results in better yield. Phosphorus is the main contributing factor towards the production of the crop.

(d) Hoeing and the ground water are the major contributing factors for the ratoon crop production. Nitrogen and potassium are the essential requirements for better yield.

The Mill Performance Model

(a) Refined sugar and cane crushed show linear relationship with time.

(b) The recovery has parabolic relationship with time.

(c) The quantity of sugar bagged has shown linear dependency upon the product of cane crushed and recovery.

Description of the District

(a) Area planted and harvested is responsive to the performance of the mill.

(b) Farmers have grievances about mill performance in terms of transportation

difficulties, weighing of the produce, and the pricing system at purchase centers.

(c) A flood in the monsoon season of one year is generallly followed by good crop yield in the following milling season.

(d) The monsoon seasons with drought or significantly less than the ordinary amount of rainfall are followed by exceptionally poor crop yield in the subsequent milling season.

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OPORTUNIDADES DE SISTEMAS DE SINCRONIZACION DE CAÑA DE AZUCAR Y MODELOS DE PRODUCCION FACTIBLE EN PUNJAB EN PAKISTAN

A. C. Early and M. K. Ayub

RESUMEN

Para este estudio se seleccionó un distrito de molienda de caña en Central Punjab, Pakistan, que consiste de un ingenio y un area productora de caña. Los objetivos del estudio fueron establecer estadisticas descriptivas del sistema en uso actual, modelos de rendimiento y modelos de funcionamiento del molino como posibilidades de produccion hacia un modelo de mejoramiento administrativo para la programación de las operaciones de molienda y recoleccion de la cosecha. El estudio mostro que el area sembrada y cosechada fue adecuada para la capacidad del molino, en terminos de transporte, peso y evaluacion en los centros de compra. La cosecha, despues de una inundacion durante la

temporada de monzon, tiene rendimientos de caña excepcionales; mientras que una sequia durante la temporada de monzon, resulta en una reduccion notable en el rendimiento de caña durante la siguiente cosecha. Para modelos de rendimiento, se empleo regresion linear y logaritmica, utilizando el numero de cultivos, numero de riegos, cantidad de fertilizante, numero de azada manual, numero de cultivos con animales, nivel freatico, edad de la caña al tiempo de la cosecha y mes de la cosecha. Los modelos lineares y logaritmicos explican la variacion de 33% a 68% en el rendimiento y los resultados incluyen unicamente las posibilidades significativas a un nivel de 99% de probabilidad con esos factores de produccion. el rendimiento de cosecha de caña de azucar da una mejor adaptacion, comparado con regresion logaritimica.

QUALITY CANE AND EXTRANEOUS MATTER

J. A. Younger

Toft Bros. Industries Limited, Bundaberg

ABSTRACT

It is an accepted fact within cane sugar production industries throughout the world, more particularly in those industries engaged in the export of raw sugar – that a clean, fresh cane supply to mills is required to promote production of raw sugar of suitable quality to satisfy the rigid and varying requirements of refiners in an increasingly competitive world marketplace. There is also an acute awareness by responsible people in the industry of the need for both the manufacturing and the cane producing sections of the industry to minimize capital expenditure and to cut operating and running costs in all sections, in order to maintain viability in the industry as a whole. It must therefore be expected that, because of the growing shortage of and the ever increasing costs of manual canefield labor, the percentage of mechanically harvested cane will increase.

While there has been a vast improvement in inbuilt technology and performance of mechanical cane harvesting equipment since initial introduction, particularly in the area of cane cleaning, it is not practical to expect that machines are capable of producing exactly the same standard of cane supply in adverse conditions as can be produced by manual cane cutters – at least not with present machine configuration. This fact must be recognized and concerted cooperative efforts made by all sections of the industry to maintain maximum efficiency within the industry with available facilities and at the same time, to strive for development of improved methods and techniques.

INTRODUCTION

Extraneous matter is the material in a cane supply other than millable cane such as tops (green leaf and vegetative growth sections), green and dried leaf, partly burned leaf material, roots, soil, etc. Depending on the quantity and type of extraneous matter in a cane supply, the detrimental effect on performance of milling equipment, sugar recovery and sugar quality may be quite dramatic. It is therefore understandable that with the incidence of the introduction of large scale mechanical chopper harvesting in many cane sugar producing countries, industry

management are looking very critically at the efficiency of cane cleaning systems incorporated in mechanical cane harvesters.

In the Australian sugar industry which is dependent on the export of high quality raw sugar for disposal of approximately 65% of annual production and in which there is virtually 100% mechanical harvesting, there is an acute awareness by all sections of the industry of the problems associated with delivery of inferior quality cane supply. This awareness has led to insistent demands by industry management on harvester manufacturers of improved efficiency of the cleaning systems incorporated in mechanical harvesters.

In an effort to overcome the extraneous matter problem, Australian harvester manufacturers are in constant liaison with responsible sugar industry management and industry bodies through the Sugar Liaison Meetings and day to day liaison with responsible sugar mill personnel and harvester owner/operators. This liaison provides for transmission of information on the effectiveness of existing technology and provides the opportunity for discussion and suggestions for introduction and testing of new technology in mechanical cane harvesters.

OBSERVATIONS AND DISCUSSIONS

Cane Cleaning System

In general, the cane cleaning system in presently available cane harvesters consists of three distinct functions:

1. Topping (usually by the action of rotating disc-mounted blades).

2. Removal of the less dense vegetative material and dust by extractor fan air displacement and/or blower fan air displacement as the cane passes through the cane harvester in conveyance toward the transport vehicle.

3. Downward disposal of denser material such as soil or stones by motion of the cane in conveyance over an 'open-roller' system and/or perforated or slatted elevators.

All functions of the cane cleaning system are interdependent. The overall efficiency of the system is very relative to operator efficiency, crop conditions and efficient maintenance of all sections of the system. For example, in badly lodged crop conditions where the mechanical topper cannot be used effectively resulting in a greater intake of top material, there is an added volume of extraneous matter placed before the other cleaning functions. If the chopper blades are allowed to become dull and do not perform the function of chopping up the tops and leaf matter, the efficiency of the function of extractor fans is reduced considerably. If the size of the extractor fan blades is reduced as a result of wear resulting in reduced air displacement, the efficiency of the extractor fan is reduced consider-

ably. If the basecutter is operated below ground level, soil intake is increased considerably.

Because of the fact that extractor fans run at a predetermined and set speed, it necessarily follows that the quality of cane sample produced must be directly relative to the volume of material, placed before the extraction system in a given time and the percentage content of extraneous matter in that volume of material. Therefore, in extreme dense crop and lodged cane conditions where the topper cannot be used effectively, or in unburnt cane conditions, it is necessary to reduce the ground speed of the harvester as compared to operation in light density, upright and well burnt crop conditions in order to maintain a similar level of extraneous matter in the cane supply.

Extraction

The function of extractors is to draw an up-draft of air through the body of chopped cane. The up-draft is most effective where the body of material is suspended. So, it is desirable to position the extractors at the top of the elevators where the cane falls either from the primary elevator into the secondary elevator or from the secondary elevator into the transport unity.

Air flow rates in the extractor system are commonly in the vicinity of 30,000 cubic feet per minute or 14 cubic meters per second with discharge velocity of approximately 30 meters per second at nominal fan speed of 2500 rpm. The extractor fans are hydraulically powered with an input engine power requirement of approximately 26 hp or 19.5 kws for each extractor. This means that for two extractors there would be an input requirements of approximately 52 hp or 39 kws. In terms of fuel consumption, approximately 11.3 liters per hour.

Looking at it from a total cost and power usage, the extraction system uses approximately 25% of total engine power output and represents approximately 25% of total capital cost of a standard type mechanical cane harvester. Cane cleaning results and loss of millable cane through extractors have been the subject of many technical papers.

Common assumptions are that in a crop of unburnt cane, extraneous matter would account for approximately 26% of total material. Depending on effectiveness of pre-harvest burning off, the quantity of extraneous matter in a cane crop may be as low as 8% or as high as 25% of total material. Cane variety, weather and crop conditions influence this figure to a large degree. But generally speaking, the extraneous matter content in burnt cane is much less than in green or unburnt cane although the added bulk in green cane is predominantly light weight leaf material.

Efforts by harvester manufacturers to improve the efficiency of extractor systems by increasing the air flow velocity, have produced an unacceptable

level of cane loss by millable cane passing out through the extractors. Tests have shown losses as high as 15 tons per hectare with only a small reduction in extraneous matter level in the cane sample. Generally, total cane losses with mechanical harvesters in most crop conditions total approximately 3%. Manufacturers pre-set extractors at what is believed to be the best compromise between engine power input, extraneous matter level and cane loss level.

The Cane Top and the Topper

A high percentage of the gross weight of extraneous vegetative material (approximately 70%) is the growth section of the plant between the last node of millable cane and the "fan" where the leaves join the growth section in mass. This section may be up to 600 mm in length and when stripped clean of leaf sheath is almost identical to a billet of millable cane in form and density. Vegetative material of this nature is commonly called cane cabbage (Fig. 1). In mechanically harvested cane, approximately 80% of extraneous matter remaining in a cane supply is cabbage. This is so because if the extractor air flow velocity is set to extract this material, it will also extract millable cane.

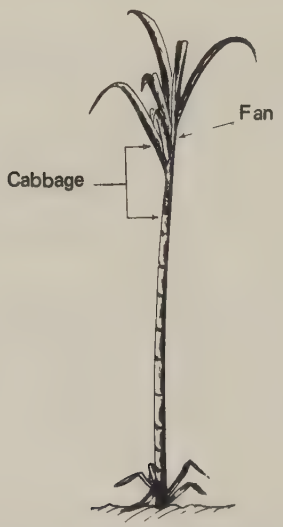

FIGURE 1. Cabbage of sugarcane

The cane topper on a mechanical cane harvester as an integral part of the cane cleaning system (Fig. 2) is regarded as the most effective means of removal of the cane top and cabbage material. However, in the light of statistics of erect cane compared to recumbent cane, the effectiveness of the topper is very much in question. This matter is presently being researched in depth by one cane harvester manufacturer in Australia.

Previous to the introduction of chopper type cane harvesters which harvest

recumbent cane successfully, sugar industries directed concentrated efforts to breeding "erect" cane varieties. But since the introduction of the chopper harvesters, this concept of cane breeding appears to be given less priority. Because of this and for other reasons such as increased crop density as a result of improved technology and techniques of cane growing, the percentage of erect cane in relation to total crop is reducing each year in the Australian sugar industry.

For most efficient results, the cane should be topped at the last node of cane or within approximately 4 inches or 100 cm above the last node of cane on the cane stalk. Of course, if harvester operators endeavor to top the cane in this exact spot, there is little margin for error before cane loss occurs. Therefore, there is a general tendency to top the cane at a point considerably above the ideal point.

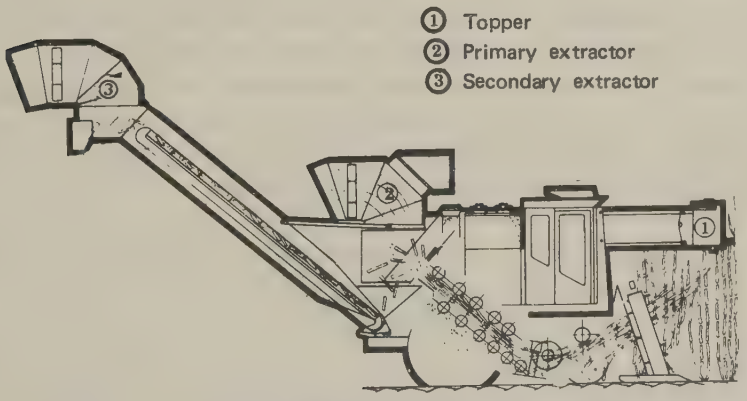

FIGURE 2. Cane cleaning system (1) topper, (2) primary extractor, (3) secondary extractor

CONCLUSION

It is unlikely that the present system of cane cleaning incorporated in mechanical harvesters will produce a greatly improved cane sample for reasons outlined above. However, a great deal of research is being directed to improving the economy of the system by improved technology resulting in reduced power input requirement and reduced capital cost. For example, the aims of one harvester manufacturer are to achieve at least the existing standard of cane cleaning with engine power input requirement reduced to 10% of total engine power output and to reduce capital cost of the system to 10% of total machine cost.

CALIDAD DE CAÑA Y MATERIA EXTRAÑA

J. A. Younger

RESUMEN

Es en hecho aceptado en las industrias productoras de caña de azúcar a traves del mundo, muy particularmente en las industrias exportadoras de azúcar cruda, que existe la necesidad de suplir caña limpia y fresca a los molinos con el fin de obtener una produccion de azúcar cruda de calidad adecuada para satisfacer las demandas extrictas y variables de las refinerias en un mercado progresivamente competitivo en el mundo entero. Ademas personas responsables en la industria estan muy concientes de que tanto la seccion manufacturera como la seccion de productoras de caña, tienen necesidad de reducir los costos de operacion y de funcionamiento en todas las secciones con el fin de mantener viabilidad en toda la industria. Por lo tanto, es de esperarse que, debido a la continua escarez de mano obrera y el aumento continuo en salarios de esta, el porciento de caña cosechada mecanicamente aumentara.

Aunque ha habido un gran progreso en la tecnologia interna y en el funcionamiento de equipo mecanico para cosecha de caña desde su introduccion inicial, particularmente en el area de limpieza de caña, no es practico esperar que las maquinas sean capaces de producir exactamente las mismas normas de abastecimiento en condiciones adversas que podria la labor manual, por lo menos no con la configuracion actual de maquinaria. Este hecho debe ser reconocido y todas las secciones de la industria deben concertar sus esfuerzos en forma cooperativa para mantener eficiencia maxima dentro de la industria con las facilidades disponibles y al mismo tiempo, esforzarse en desarrollar mejores metodos y tecnicas.

BEHAVIOR OF A SUCTION PNEUMATIC CHAMBER FOR SUGARCANE EXTRANEOUS MATTER REMOVAL UNDER VARYING VEGETAL MASS FEEDING RATES

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ABSTRACT

This work comprises a study of the behavior of a removal chamber with a progressive increase in feed vegetal mass of a constant initial extraneous matter composition; a repetition of some of the previous tests using another composition so as to establish a comparison of the results obtained; a study of the possibility of affecting chamber performance as a result of variations in the deviation of expelled extraneous matter; and, finally, a review of the behavior of response indicators when the revolutions of the axial fan are increased.

The results obtained led to new criteria regarding the dimensions of future harvester removal chamber as well as to a possible moving of propeller location nearer the scattering area of vegetal mass, and a likely reduction in axial fan power consumption.

INTRODUCTION

As a result of a research work carried out during 1976 on an extraneous matter removal system by suction at a test bench scale, among other conclusions arrived at, it was established that the removal chamber used was overdimensioned. Therefore, a recommendation was made to undertake a new study to investigate this matter.

A study was prepared which would involve: 1) behavior of the chamber with a progressive increase in vegetal mass feeding and a constant composition of initial extraneous matter; 2) repetition of some of the tests mentioned in paragraph (1) but using a different initial composition; 3) possible effect of a higher or lower deviation of expelled extraneous matter on chamber performance; and 4) behavior of response indicators with an increase in the revolutions of the axial fan propeller.

MATERIALS AND METHODS

Experimental design

The cane harvesters used in Cuba normally operate on green cane with a

feeding mean load of 14 kg of clean cane (19.4 kg of vegetal mass with 26% of extraneous matter). This does not mean that for different reasons such as: adequate agricultural yields, erect varieties, well prepared fields, etc., they could not process feed rates slightly higher than mentioned above.

Due to these considerations it was decided to test the performance of the pneumatic removal chamber of the harvester with feeds increased up to a maximum which was approximately double the highest values attained in the field under operating conditions, and to quantify the behavior of the facility in the customary study indicators, including also in this case power consumption by the axial fan rotor.

Experiments were designed for intervals of 4 up to 40 kg of vegetal mass feeding. Ten experimental points or runs were carried out with two repetitions of each one. Table 1 shows the weights in kilograms to be distributed on the feeding apron of the set up (Fig. 1) partial weights of each one of the components which make up a vegetal mass containing in every case 28% of initial extraneous matter.

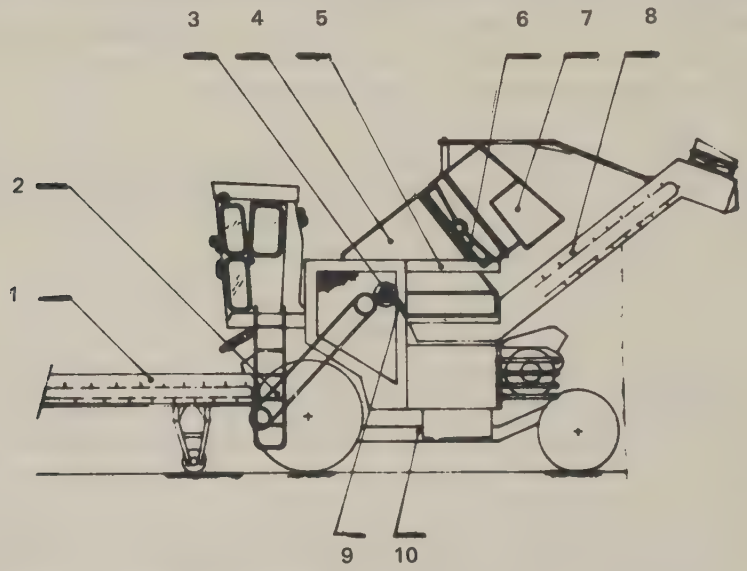

FIGURE 1. Experimental set-up

Chamber performance was also tested for similar feed increases with a different initial composition of extraneous matter repeating points which appear in Table 1.

Table 2 shows the partial and total weights of the different vegetal mass components, but this time with 21% extaneous matter.

Various experiments were made varying the width of the deviation spiral of extraneous matter at its outlet to the exterior as well as to verify power consumption by the chamber by increasing the rotation speed of the axial fan propeller.

TABLE 1. Distribution of vegetal mass in weight according to feed mass in Kg/sec for an initial extraneous matter composition of 28%.

Corrida	Alimentacion kg/s	Masa Total Kg	Cana Limpia kg	Tallo Verde kg	Penacho kg	Hojas Verdes kg	Hojas Secas kg
1	4	9.5	6.8	0.7	0.4	0.9	0.7
2	8	18.9	13.6	1.4	0.8	1.8	1.3
3	12	28.6	20.6	2.1	1.2	2.7	2.0
4	16	38.2	27.6	2.8	1.6	3.6	2.7
5	20	47.5	34.2	3.5	2.0	4.5	3.3
6	24	57.1	41.1	4.2	2.4	5.4	4.0
7	28	66.7	48.0	4.9	2.8	6.3	4.7
8	32	76.1	54.8	5.6	3.2	7.2	5.3
9	36	86.7	61.7	6.3	3.6	8.1	6.0
10	40	95.3	68.6	7.0	4.0	9.0	6.7

TABLE 2. Distribution of vegetal mass in weight according to feed mass in Kg/sec for an initial estraneous matter composition of 21%

Run	Feed kg/sec	Total Mass kg	Clean Cane kg	Green Stalks kg	Tops kg	Green Leaves kg	Dry Leaves kg
11	8	18.9	15.0	0.9	0.5	1.2	1.3
12	24	57.1	45.1	2.8	1.6	3.6	4.0
13	40	95.3	75.2	4.7	2.7	6.0	6.7

The differences in absolute percentages of the two morphological compositions used are shown in Table 3.

TABLE 3. Differences in absolute percentages of the two morphological compositions.

Clean Cane %	Extraneous Matter %	Extraneous Matter Stalks %	Tops %	Green Leaves %	Trash %
72.0	28.0	7.4	4.2	9.4	7.0
79.0	21.0	4.9	2.9	6.2	7.0

Equipment used and their characteristics

A Libertadora 1200-B harvester was used for this study as a facility at a test bench scale. The front part of the machine which enclosed the bottom cutting elements and the chopper, among other things, was removed and substituted with a 5 meter long feeding apron with a linear speed of 2.1 m/sec and driven by a 2.8 kw electric motor.

Vegetal mass fell onto the feeding apron in the amounts programmed by Tables 1 and 2. The mass was suitably chopped so as to simulate the actual work of the bottom cutting element and the chopper under operating conditions.

Power consumption and the revolutions of the pnuematic chamber propeller were measured using:

1 — 8AH7M amplifier,
1 — H-700 oscillograph,
1 — mercury collector and
1 — inductive revolution counter

Tensometric sensors were sembridge mounted on the axis of the axial fan and the oscillograph was set at a speed of 16 cm of paper per second, recording for approximately 10 to 15 seconds. The driving axis of the propeiler was calibrated by three repetitions under load and without load before being mounted on the machine. There was a variation of 10% of its nominal load at each step, Came[3].

Response Indicators

The facility responses studied were obtained by the following relations:

$$ME = \frac{ME_f}{CL_f + ME_f} \times 100$$

$$E = \frac{ME_o - ME_f}{ME_o} \times 100$$

$$P = \frac{CL_o - CL_f}{CL_o} \times 100$$

$$N = \frac{M\ n}{716.2}$$

where:

ME = Residual impurities or extraneous matter not separated by the removal chamber
E = Extraneous matter removal efficiency of the pneumatic chamber

P	=	Clean cane losses due to removal operation
ME_o	=	Initial extraneous matter of feed vegetal mass
ME_f	=	Final extraneous matter
CL_o	=	Initial clean canes in feed vegetal mass
CL_f	=	Final clean canes after they have undergone the cleaning process in the removal chamber
M	=	Torque measured on the axial fan driving axis
n	=	Revolutions per minute of the axial fan axis
N	=	Power consumed by the axial fan

RESULTS

Tables 4 and 5 show the results obtained from the designs proposed in Tables 1 and 2. The data were corrected for the actual amount of feed processed by the removal chamber as a result of losses occurred on the longitudinal conveyor of the harvest due to a fault in the mounting of the spreader drum. These tables also show the effective revolutions of the fan propeller, power consumption, and the three characteristic response indicators for the evaluation of cane harvesters measured in their mean values. Runs were satisfactorily carried out. (Peralta Abreu[1]).

TABLE 4. Results obtained from designs proposed in Tables 1 and 2

Corrida No.	Alimentacion Real kg/s	Rotacion Helice rpm	Potencia Consumida hp	Impurezas Residuales %	Efficiencia Camara %	Perdidas de cana %
1	3.2	1,185	45.50	14.8	56.9	1.5
2	6.4	1,176	47.86	15.1	56.1	1.6
3	9.8	1.131	47.37	16.3	52.6	0.3
4	13.1	1.176	51.8	15.8	53.7	0.2
5	16.8	1,194	53.34	14.8	54.5	0.5
6	19.6	1.164	54.77	16.4	52.7	0.0
7	23.6	1.188	60.04	16.5	50.6	1.6
8	27.1	1,146	57.60	15.8	52.3	1.1
9	30.1	1.158	60.63	16.4	51.5	0.5
10	33.2	1.170	59.95	16.8	50.6	0.6

The results of the increase in deviation spiral width and the results of the increase in propeller revolutions are shown in Table 6.

DISCUSSION

Efficiency of the removal chamber

From the results shown in Table 4 it may be seen that the chamber efficiency

TABLE 5. Results obtained from designs proposed in Tables 1 and 2

Run No.	Actual Feed kg/sec	Propeller Rotation rpm	Power Consumption hp	Residual Impurities %	Chamber Efficiency %	Cane Losses %
11	7.5	1.200	46.57	10.0	58.6	0.0
12	22.9	1.188	53.90	10.8	56.4	0.2
13	37.9	1.176	57.46	11.2	55.2	0.9

TABLE 6. Results of the increase in deviation spiral with an increase in propeller revolutions.

Item	Initial Extraneous Matter %	Actual Feed kg/sec	Propeller Rotation rpm	Power Consumption hp	Impurities %	Efficiency %	Losses %
Wide Deflector	28	22.1	1.200	45.90	20.5	36.7	1.1
Propeller at — 1300 rpm	21	22.9	1.287	66.00	10.2	59.6	0.6
Propeller at — 1300 rpm	28	22.6	1.278	65.94	15.4	55.7	0.5

remains almost constant, with only a small tendency to decrease as feed is increased.

This result is illustrated in **Fig. 2** where the minimum squares method was used.

If the vegetal mass fed to the harvester were very long, the chamber efficiency would drop more or less sharply. However, it was found that the axial fan kept its performance pattern and was not affected by the load to which it was subjected, notwithstanding the fact that it had to handle more than double the mass that was normal in actual field operation.

By reducing the initial extraneous matter composition to 21% (Table 5) the efficiency increased slightly as cane field impurities decreased with the same feed rate. This would be easily understood, since it was known that while cane field extraneous matter decrease, there was an increase in the specific weight of dry leaves in relation to total impurities. It was precisely here where pneumatic removal chambers were most efficient.

Fig. 1 shows the curve corresponding to the 21% composition and efficiency behaved similarly as the above where extraneous matter composition was 28%.

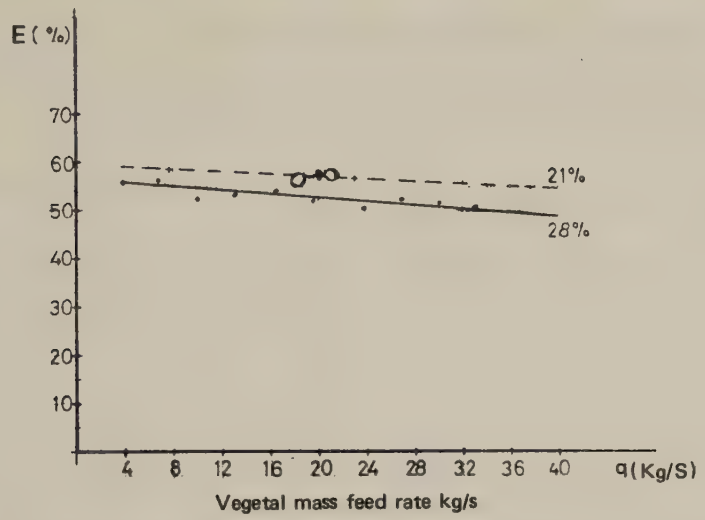

FIGURE 2. Efficiency of the removal chamber vs. productivity determined by minimum squares method.

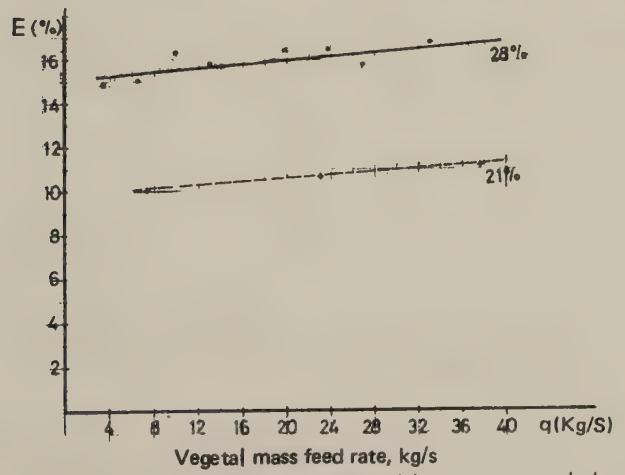

FIGURE 3. Extraneous matter not separated by the removal chamber determined by minimum squares method.

Cane losses in the removal chamber

In all experimental runs (Tables 4, 5 and 6) cane losses remained within a very narrow scale of values. It was found that feed variations exerted no influence on this indicator. Although it has already been demonstrated in a previous work, it should be emphasized that a change in the composition of initial extraneous matter did not have any influence on losses due to the performance of this chamber.

Extraneous matter not separated by the removal chamber

The results of this response, which are shown in Tables 4 and 5, were processed by the minimum squares method and they appear on Fig. 3.

Fig. 3 shows that the quality of the harvest was maintained and that it was affected only very slightly by feed increases.

The different extraneous matter components were not studied separately in the mass received, but it should be pointed out that all the green stalk of the top and most of the top leaves were recovered without having been removed by the chamber.

By studying the data shown in Table 3 and Fig. 3 it is easy to demonstrate how any increase in initial extraneous matter would bring about a proportional increase in the impurities received from the harvester. The green stalks of the top and the top leaves in the initial mass were increased. The removal chamber was virtually unable to do an effective removal work on these two components, specially on the green stalks.

Power consumption by the axial fan

Fig. 4 shows the values resulting from power consumption (Table 4) due to feed increases for an initial extraneous matter composition of 28%.

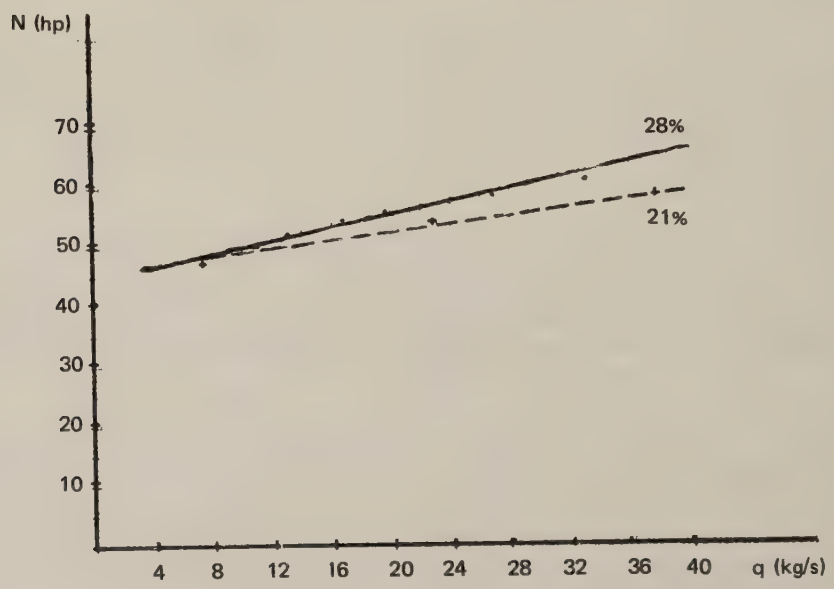

FIGURE 4. Values resulting from power consumption due to feed increases for an initial extraneous matter composition of 28%.

From the data plotted in Fig. 4, it could be seen that in all the areas investigated no inflexion tendency of the curve toward lower power consumption values was appreciated. As feed rates were increased, the power requirements of the fan also increased by a ratio of 0.54 HP and 0.36 HP per kilogram of increase in feed mass for initial extraneous matter compositions of 28% and 21%, respectively.

It should be emphasized that these power consumption values per kilogram of increase in feed mass were by no means a generalized result as it applied only to the chamber studied herein and to the constructive condition at the time of the experiment.

Table 7 shows some of the data received which appear in Tables 1 and 4, knowing the feeding apron was 5 meters long and had a linear speed of 2.1 m/sec.

TABLE 7. Representation of results corresponding to tests made with 28% initial impurities

Corrida No.	Caña Inicial kg/s	Perdidas en Caña %	Caña por Ventilad. kg/s	M.E. Inicial Kg/s	Efic. Camara %	M.E. por Ventilad kg/s	Total por Ventilad kg/s
1	2.3	1.5	0.035	0.9	56.9	0.512	0.547
2	4.6	0.3	0.014	1.8	56.1	1.010	1.024
3	7.1	0.3	0.021	2.7	52.6	1.420	1.441
4	9.4	0.2	0.019	3.7	53.7	1.987	2.006
5	12.1	0.5	0.061	4.7	54.5	2.562	2.623
6	14.1	0.0	0.000	5.5	52.7	2.898	2.898
7	17.0	1.6	0.272	6.6	50.6	3.340	3.612
8	19.5	1.1	0.215	7.6	52.3	3.975	4.190
9	21.7	0.5	0.109	8.4	51.5	4.326	4.435
10	23.9	0.6	0.143	9.3	50.6	4.706	4.849

Fig. 4 illustrates the curves for power consumption by the chamber, extraneous matter removed and clean cane losses by the axial fan propeller by unit of time, in each run made with an initial composition of 28%.

Each of the curves plotted in Fig. 5 were related to their particular scale and all of them were vertically related to the corresponding run number of the experiments.

It would be seen that the extraneous matter mass removed by the chamber increased almost constantly without undergoing any modification, which was expected since extraneous matter removal efficiency (Fig. 2) was almost constant and vegetal mass increase by run (Table 1) also showed a constant slope.

The most interesting characteristic which statistically explained the variations in power consumption was the clean cane loss curve caused by the cleaning processing. In almost every run where loss increases occurred, there were proportional increases in power consumption.

Based on the above experience, power consumption due to extraneous matters and for cleaning cane lost by the removal process could be calculated. By applying the minimum squares method to the relation between removed extraneous matter and power consumption, on the one hand and losses in each run, on the other, the following results were obtained.

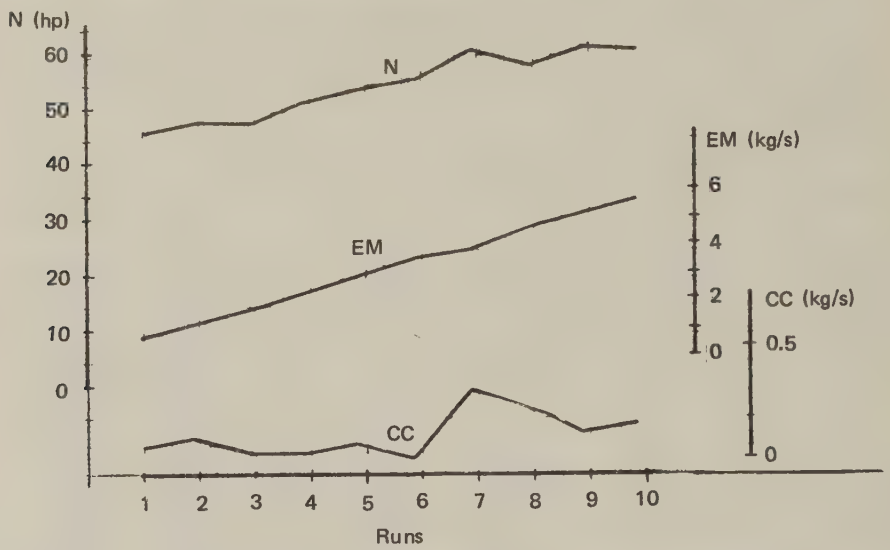

FIGURE 5. Curves for power consumption by chamber, extraneous matter removed and clean cane losses vs. number of runs.

$$N = 43.66 + 3.24\ m$$
$$P = 0.02\ c$$

where:

N	=	power
m	=	mass of impurities per second which pass through the axial fan
P	=	cane lost by the fan in a unit of time
C	=	corresponding run

The first equation demonstrates that for each kilogram by second of extraneous matter removed by the axial fan, power consumption increased by 3.24 hp (2.4 kW). If both relations were taken and results were obtained for the most significant cases (Table 7), it will be found that for each kilogram by second of clean cane lost through the axial fan propeller studied, power consumption increases above 8 hp (6 kW).

These results, specially the last one, should be accepted with reservation and be regarded only as examples. This matter should be studied further so as to arrive at accurate conclusions based on further data. However at present, it might be as-

certained that it is perfectly valid to assume that power consumption due to cane losses is higher than power consumption by an equivalent extraneous matter mass by unit of time.

Tables 8 and 9 show processed values corresponding to the results of tests made with 21% initial impurities and a comparison between these results and those for 28%.

TABLE 8. Processed values corresponding to the results of tests made with 21% impurities.

Corrida No.	Caña Inicial kg/s	Perdidas en Caña %	Caña por Ventilad kg/s	ME Inicial kg/s	Efic. Camara %	M.E. por Ventilad. kg/s	Total por Ventilad. kg/s
11	5.8	0.0	0.000	1.7	58.6	0.996	0.996
12	17.8	0.2	0.036	5.1	56.4	2.876	2.912
13	29.5	0.9	0.266	8.4	55.2	4.637	4.903

TABLE 9. Power specific consumption vs. feed mass

Initial 21 %	Ext. Matter 28%	Ext. Matter by fan 21 %	28 %	Power Consumption 21%	28%
1.7	1.8	0.996	1.010	46.51	47.86
5.1	5.5	2.876	2.898	53.90	54.77
8.4	9.3	4.637	4.706	57.46	59.95

According to Table 9, power consumption for the tests carried out with 21% initial extraneous matter was lower than that for the tests made with 28% initial extraneous matter. This result corresponds to the respective masses that passed by the fan in each case and which also depended on the initial masses for each extraneous matter composition. It may be easily established that, under identical feeding conditions, as extraneous matter present in a cane field increase, the power required by the removal chamber would proportionately increase.

Gross power consumption, net specific consumption and effective power consumption indicator. The general power consumption by unit of mass feed per second was derived from the following relation:

$$C_{eg} = \frac{N}{q}$$

where:

C_{eg} = gross power consumption in hp--s/kg
N = power consumption in hp
q = vegetal mass feed by unit of time in kg/s

All the points obtained from the above equation have been plotted on Fig. 6 with data from Table 4 and 5, for the two initial compositions used.

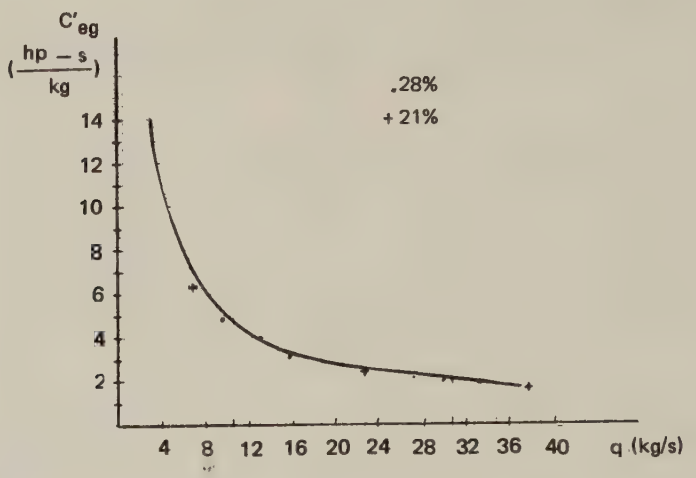

FIGURE 6. Global specific power consumption vs. feed mass

Fig. 7 shows the points corresponding to the gross specific power consumption per unit of mass removed per second by the axial fan and which were derived from:

$$C'_{eq} = \frac{N}{q'}$$

where:

C'eq = gross specific power consumption per unit of mass removed
q' = mass removed by the axial fan in a unit of time

As it can be seen in both figures, all points — regardless the morphological composition to which they may belong — were roughly plotted on the same curve. This indicated that the chamber that was studied through such indicators underwent the same variation, irrespective of feed vegetal mass changes; and these points showed the removal chamber performance patterns, provided chamber physical factors remain unchanged.

On the other hand, the net specific power consumption per unit of feed mass per second is given by the following relation:

$$C'_{en} = \frac{N - Nx}{q'}$$

where:

C_{en} = net specific power consumption in hp-s/kg
N = total power consumption
Nx = power consumption under dry conditions
q = vegetal mass feed rate in kg/s

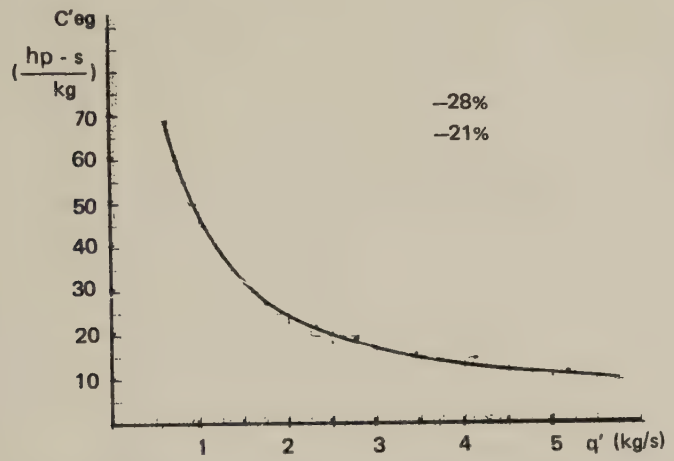

FIGURE 7. Points corresponding to the global specific power consumption by unit of mass removed by second.

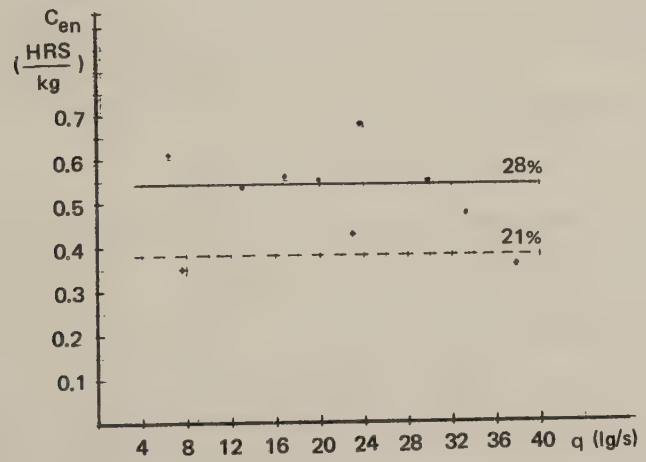

FIGURE 8. Points obtained for the net specific power consumption by second.

Fig. 8 shows the points obtained for the net specific power consumption per unit of mass feed power second. For 28% initial extraneous matter, the results were about 0.54 mean value, and that for 21% initial composition, the results were about 0.38 mean value.

The net specific power consumption per unit of mass removed per second through the axial fan is given by equation:

$$C'_{en} = \frac{N - Nx}{q'}$$

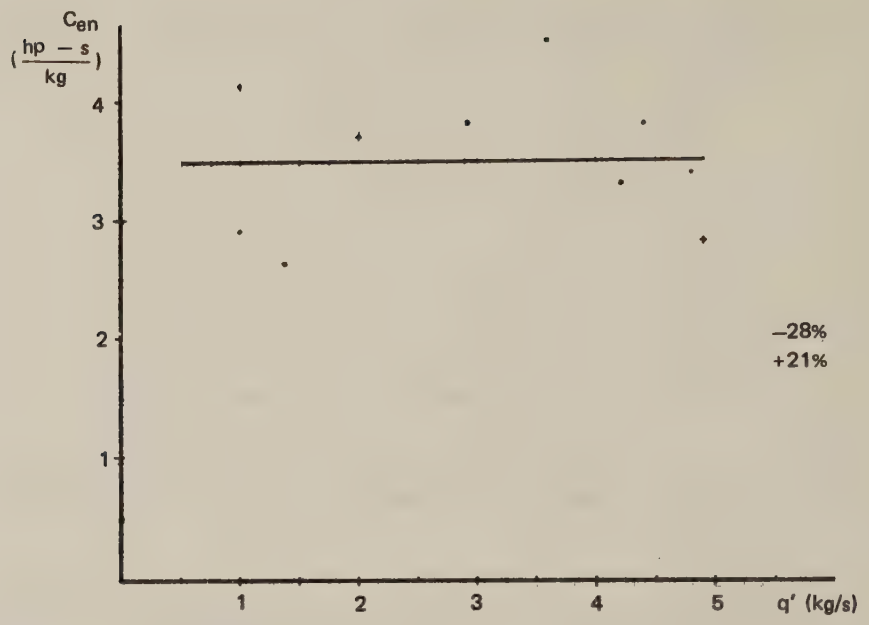

FIGURE 9. Net specific power consumption per unit of feed mass by second.

where:

C'_{en} = net specific power consumption

q' = vegetal mass removed in a unit of time

The results are shown in Fig. 9.

Where specific power consumption as related to mass feed rate (Fig. 8) is concerned, such consumption depended exclusively on the initial extraneous matter composition and that its value increased proportionally as impurities contained in the initial mass increase.

As expected, the indicator net specific power consumption, as related to the mass removed by the fan (Fig. 9), was influenced neither by a change in initial composition nor by a variation in feed. A consumption mean value obtained was 3.5 HP (2.6 kW) per gram of vegetal mass removed (extraneous matter + lost cane) per second.

Fig. 10 are plotted the curves corresponding to the indicator effective power consumption as related to feed mass indicator power consumption is expressed as:

$$I_p = \frac{N - NX}{N} \times 100$$

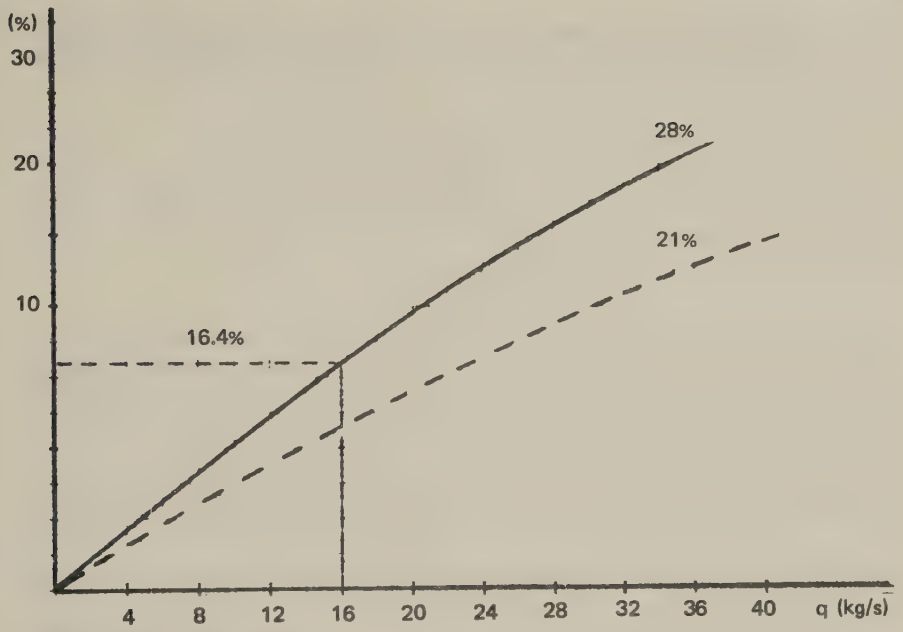

FIGURE 10. Power specific consumption vs. feed mass

CONCLUSIONS

Cane losses which occurred during the removal process were not influenced by feed variations.

Power consumption by the chamber was directly proportional to initial extraneous matter composition.

Power consumption increased in a higher proportion with cane loss through the axial fan than with an equivalent mass of removed extraneous matter.

Effective power consumption for extraneous matter removal was very low in relation to total consumption: about 15% for feeds of the order of 16 to 20 kg/s.

A deviation in the flow of matter expelled by the axial fan provoked a reduction in the removing efficiency of the fan.

Whenever axial fan revolutions were increased during the removal process, a significant increase also occurred in power consumption.

RECOMMENDATIONS

Based on the results of the present work, if may be assumed that chambers provided with smaller axial fans may give at least, the same performance in ex-

traneous matter removal as present fans do. Therefore, as investigation in this sense is recommended, including also studies on the possibilities of placing the propeller nearer the scattering area of vegetal mass and a reduction in propeller rotation.

The study of the effect of the vegetal mass spreading drum on the removal chamber, taking into account its right location and driving as well as its shape, in order to suppress the effect on cane losses and increase its efficiency in extraneous matter removal is recommended new ways varying of extraneous matter.

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CAMARA PARA REMOVER LA MATERIA EXTRAÑA DE LA CAÑA DE AZUCAR BAJO AUMENTO PROGRESIVO EN ALIMENTACION DE UNA MASA VEGETAL

Urioste A. Peralta Abreu y Lino E. Abreu

RESUMEN

Este trabajo abarca un estudio sobre el funcionamiento de una camara de aspercion con aumento progresivo en alimentacion de una masa vegetal con una cantidad constante de materia extraña; la repeticion de algunas pruebas previas usando un compuesto diferente para establecer una comparacion de los resultados obtenidos; un estudio sobre los efectos en el funcionamiento de la camara como resultado de las variaciones en la deviacion de materia extraña expulsada; y finalmente, una revision del funcionamiento de los indicadores al aumentarse las revoluciones del ventilar axial.

Los resultados dictan nuevas normas sobre las dimensiones futuras de la camara de aspersion en maquinas cosechadoras asi como relacalizacion del propulsor mas cerca del area de dispersion de materia vegetal y posiblemente reduccion de consumo de potencia del ventilador axial.

ANALYSIS OF THE CUTTING PROCESS IN THE CHOPPER OF KTP – 1 SUGARCANE HARVESTERS

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ABSTRACT

The sugarcane chopper is one of the most important working parts of sugarcane harvesting machines.

The study of the cutting process in the chopper permits one to know the influence of every factor playing a role in it, and allows one to establish the parameters that characterize the best functioning of the drums which make up this chopper.

By the application of ultrarapid filming techniques and tensometric measurements it is possible to obtain data that will contribute to explain the functioning of the chopper parts which, at first sight and using conventional methods of measurement, is not possible due to the revolution frequency (300 rpm) of the drums that make up the chopper.

The influence of drum and knife geometry in the cutting and stalk throwing processes by the chopper are pointed out in this paper.

The data furnished by this work may be of help for an accurate determination of the chopper functioning characteristics, and may contribute to develop existing design criteria so as to make possible the modernization of the apparatus.

INTRODUCTION

Among the working parts of the harvesting machine, the chopper is particularly important. The chopping of stalks and leaves in pieces of a given length (250-400 mm) makes possible the separation of leaves from stalks by means of an air current, a more rational use of transportation means during the harvesting process, and the optimization of the harvested mass processing by the sugar mill.

Mass chopping is one of the most power consuming operations among those carried out by the harvester.

Although choppers are widely used in sugarcane harvesters, the factors in-

fluencing the chopping process of the vegetable mass are unknown up to the present, independently of the geometric and kinematic parameters that play a part in the cutting process and which undoubtedly influence the quantitative and energetic indicators of chopper performance.

This analysis of the chopper cutting process of the KTP–1 sugarcane harvester is designed to clear up some unknown facts in relation to the work and functions carried out by these components of the chopper, thus contributing to bring up to date the work of this part as a point of reference for its modernization in future harvester prototypes.

THEORETICAL CONSIDERATIONS

While the drums of the chopper are working, the upper and lower knives (Fig. 1) of the drums rotate at velocity w and they grab stalk layers. They compress and draw the stalk layer towards them, penetrate the layer and then constitute a cutting pair which chops the layer.

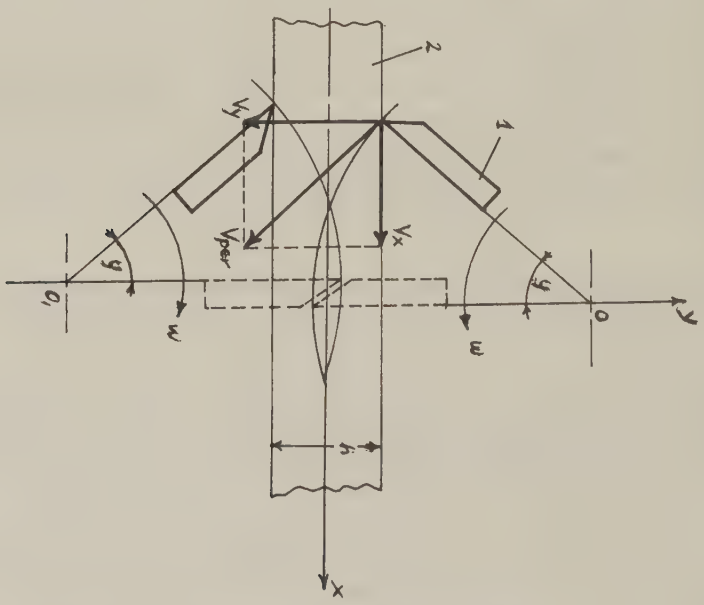


FIGURE 1. Diagram for the analysis of chopper performance

Once the cutting process is over, the knives continue to rotate and perform an action of throwing the cut pieces of stalks onto a conveyor. The absolute trajectory of the movement of the cutting edge in coordinates x-y may be represented by circumference equations:

for the upper knife

$$x^2 + [y - (R - \frac{S}{2}]^2 = R^2$$

for the lower knife

$$x^2 + [y + (R - \frac{S}{2})]^2 = R^2$$

where

R = drum radius up to the extreme of the knife cutting edge

S = overlapping of knife cutting edges

Knife cutting edge peripheral velocity V may be resolved in Vx and Vy

thus:

$$Vy = V \text{ per } \operatorname{Sin} \varphi \; ; Vx = V \text{ per } \operatorname{Cos} \varphi$$

where

φ = the rotation angle of the upper and lower knives from the moment of contact of their cutting edges with the material to be cut up to the moment of coincidence with axis y. Component Vy represents the vertical displacement velocity of the knife outer edge, while the component Vx represents the attracting velocity of stalks by the knives or the displacement velocity of stalks in the direction of axis x without considering their sliding. The importance of determining the values of angle V can be inferred from these formulas in order to know the relation existing between Vx and Vy.

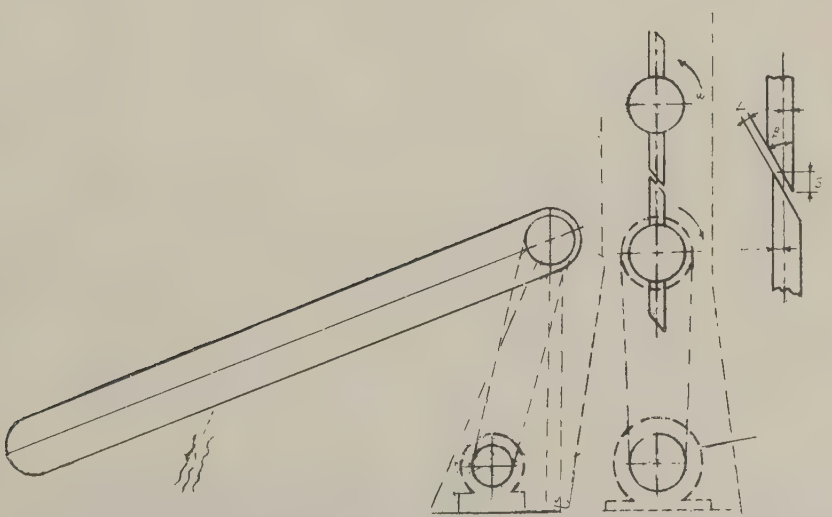


FIGURE 2. Diagram of the experimental installation

MATERIALS AND METHODS

To study the cutting process of the mass of stalks of cane leaves, a two-drum chopper installation was used whose diagram is shown in Fig. 2. This installation consisted of a slat conveyor 1 which had the possibility of varying the feeding angle of stalks of a two-drum chopper 2; of independent driving mechanisms 3, and of chassis 4.

Stalks with leaves attached were carried by a conveyor driven by an electric motor through a reducer which was also driven by another electric motor. The installation was prepared for measuring the rotational movement of the chopper.

For the cinematographic investigations of the cutting process, windows were opened on the lateral walls of the installation, through which the cutting process was observed.

For these ultrarapid filmings a German "Practika" camera was used.

Table 1 shows the parameters that characterized the experimental conditions.

TABLE 1. Parameters established in the experiments

No.	Parameter denomination	Established dimensions
1.	Feeding capacity, kg/sec.	10
2.	Feeding velocity of the mass, m/sec.	1
3.	Feeding angle of the conveyor, grades	0
4.	Rotation frequency of the chopper, RPM	300
5.	Free spaces between the knives, mm	1
6.	Recovering of the knives, mm	10
7.	Sharpening of the knives, μk	100
8.	Sharpening angle of the knives β, grades	20

Experiments were made on variety My 53 174 which in preliminary investigations proved to be more resistant to the cutting process (Silveira[2]).

Tests were carried out three times.

Tensometric measurement of the cutting process

With the objective of establishing the indicators of energy requirements of the chopper cutting process, tensometric measurements of the process were made. Considering the specific work of each drum, the upper one and the lower one were measured independently.

For measuring the rotation moment (Me) a tensometric pulley made

for this purpose was placed at the entrance of the lower drum. Extensometers were fixed on the pulley according to a Wheatstone bridge connection. The rotational moment (Mz) of the upper drum was determined by extensometers attached to the shaft. The signals from the extensometers were caught by annular and terminal collectors. A Soviet amplifier 8AH4—7M was used for the amplification of electronic impulses.

The number of revolutions of the shafts was measured with an electric induction tachometer. An oscillograph H-700 was used to record all measured parameters on a special paper and thus oscillograms were obtained. A planimeter was also used.

The tensometering process was coordinated with ultrarapid filming.

Ultrarapid filmings

At the beginning, the velocity of the filming process was determined considering the rotation frequency of the drums in the chopper. Then, the frequency and the filming time of the cinematographic camera was calculated. The camera was placed in front of one of the lateral windows of the installation. This window was covered with transparent acrylic material.

The lighting of the objective was determined with the help of a photometer, taking into consideration the sensitivity of the film used. The last determination of the light intensity was made after some test filmings.

The filming velocity ranged between 100 and 300 pictures/second. When the filming of the objective was finished quantitative and qualitative analyses of the film process were carried out on a montage table.

RESULTS

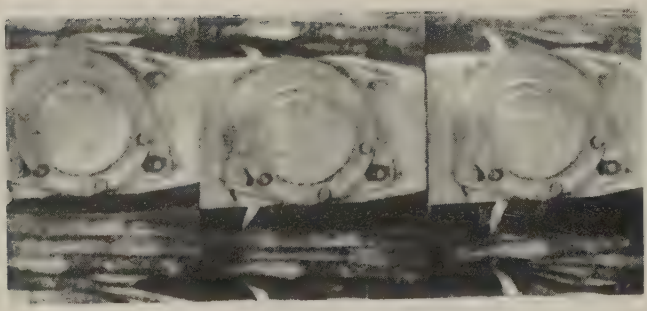
The work movement of the cutting edge of the two-drum chopper knives represented a curvilinear surface with the shape of a trochoid loop.

During the cutting process, the knives not only penetrated the material but they also attracted it towards them. The penetration angle of the knives cutting edge varies in relation to the cutting surface, thus causing a compression of the material by the two faces of the knives cutting edge. Part of the power was consumed in this way.

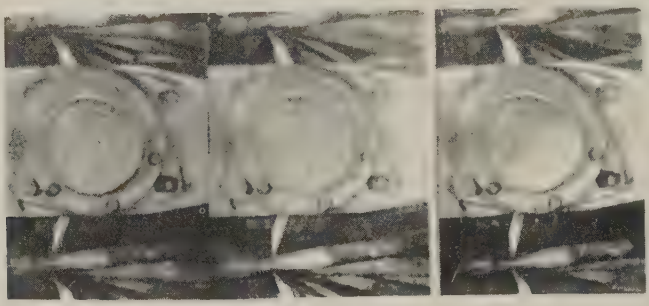
The results of the analysis of the fast filmed pictures showed that the chopper had the following characteristic fundamental phases of interaction with the mass of leaves and stalks:

1. Grabbing and formation of a layer in the mass
2. Cutting process in the mass
3. Throwing of the chopped mass

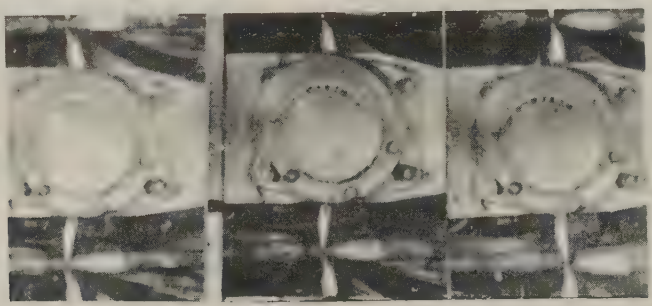
These three phases were highly significant for the fulfillment of the chopper



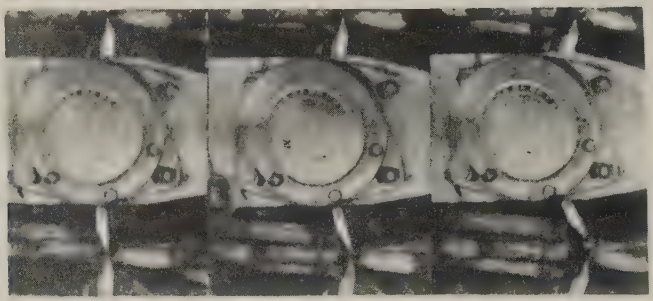
FIGURES 3-a, 3-b and 3-c. Grabbing and formation of a layer in the mass.



FIGURES 3-d, 3-e and 3-f. The cutting process.



FIGURES 3-g, 3-h and 3-i. The cutting process.



FIGURES 3-j, 3-k and 3-l.

FIGURES 3-m, 3-n and 3-o. Pith particles being detached from the cut stalks.

TABLE 2. Values of the circumference arches described by the border of the knives (in grades) and the velocities V_x and V_y (in m/sec.)

Velocities (m/sec)			Holding angle and formation of the layer $\alpha_2 - \alpha_1$ grades	Direct cutting angle $\alpha_3 - \alpha_2$ grades	Throwing angle $\alpha_4 - \alpha_3$ grades	Total worki angle of the chopper $\alpha_4 - \alpha_1$ grades
$\alpha_1 = 46^o$	$Vx_1 = 3.46$	$Vy_1 = 3.56$				
$\alpha_2 = 66^o$	$Vx_2 = 4.56$	$Vy_2 = 2.00$				
$\alpha_3 = 81.5^o$	$Vx_3 = 4.96$	$Vy_3 = 0.73$	20^o	15.5^o	32.5^o	68^o
$\alpha_4 = 114^o$	$Vx_4 = 4.56$	$Vy_4 = 2.00$				

TABLE 3. Used power in the drum transmission of the chopper

Total power	Upper drum		Lower drum		Relation
Ne, kw	Nz		Ne —	Nz	Nz/Ne — Nz
	Kw	%	Kw	%	
11.4	6.91	60.6	4.48	39.4	1.54
9.9	6.28	63.4	3.61	36.6	1.73
10.95	5.53	50.5	5.42	49.5	1.02
13.23	6.68	50.5	6.55	49.5	1.02
12.42	6.59	53.04	3.66	44.96	1.12
8.14	4.48	55.05	3.66	44.95	1.22
6.92	3.53	51.0	3.39	49.0	1.04
12.22	7.25	59.38	4.96	40.62	1.46
12.42	7.25	58.4	5.16	41.6	1.405
Average		55.7		44.3	1.28

technological process.

Fig. 3 shows the filmed pictures. It may be seen that the knives of the upper and lower drums, while rotating, grabbed the stalk mass (Fig. 3-a), then the mass was compressed by the knives and drawn towards them (Fig. 3-b).

In the layer formation process (Fig 3-c) the upper knife acted more intensively upon the mass. The figure shows the beginning of the cutting process (Fig. 3-d), and its end (Fig. 3-h). In this phase, the knives get into the stalk layer at the same time (Figs. 3-d, e, f, g) and when they meet the cutting pair which cuts the stalk layer is constituted (Fig. 3-h).

The pictures show that the upper knife played a more active role during the cutting process than the lower one.

After the cutting process was completed, the throwing process of the cut mass of stalks and leaves onto the conveyor began (Fig. 3-i). After the cutting process, the lower cut plane of the chopped stalk fell and lay on the lower knife face. From that moment, the throwing action of the chopper was carried out only by the lower knife up to the last moment of the throwing (Fig. 3-k) when the contact between the knife and the material was lost.

In the course of the cutting process pith particles were detached from the stalk, thus causing juice losses. This phenomenon is shown in Fig. 3-1, m, and o

The results of the filmed pictures are shown in Table 2. The circular arc described by the border of the knife cutting edge ($\alpha_2 - \alpha_1$) corresponded to the grab and layer formation phase and was 23% of the total working arc; ($\alpha_3 - \alpha_2$) corresponded to the direct cutting phase and was 30%, and ($\alpha_4 - \alpha_3$) corresponded to the throwing phase and was 47%.

The analysis of the oscillograms obtained led to the conclusion that the power used for driving the upper drum was more than the power used for driving the lower drum (see Table 3). This meant that the knives cutting edges of the upper drum had a greater activity for penetrating the mass of stalks and leaves. Therefore, the internal action of the cutting edges of the upper drum brought about a reduction in the drum cutting capacities during a short period of exploitation.

CONCLUSIONS AND RECOMMENDATIONS

1. The arc of the circle described by the border of the knife cutting edge in the grab and stalk layer formation phase was 23% of the total working arc; 30% during the direct cut phase and 47% during the phase of chopped mass throwing.

2. The power used for driving the upper drum of the radial-type chopper was 28% higher than the power used for driving the lower drum.

3. Losses occurring in the chopper during the cutting process might be con-

siderable in relation to the amount of stalk particles detached. Hence, it is recommended that this phenomenon be further investigated.

4. The results of this work could be used as initial data for future investigations on drum knives wear and durability, and also a design criteria for new and more efficient choppers.

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ANALISIS DEL PROCESO DE CORTE DEL TROZADOR DE LAS COSECHADORAS DE CAÑA KTP – 1

Juan Silveira Remus

RESUMEN

El trozador de caña es una de las piezas de mayor importancia en el proceso tecnologico de las maquinas cosechadoras de caña de azucar.

El estudio del proceso de corte del trozador da a conocer la influencia de cada uno de los factores que toman parte en el proceso, y permite establecer los parametros que caracterizan el mejor funcionamiento de los cilindros de que se compone el trozador.

El uso de tecnicas de filmacion ultrarapidas y medidas tensometricas permite obtener informacion contributiva a la explicacion de funcionamiento del trozador, lo cual no seria posible a primera vista y usando metodos de medida convencionales debido a la velocidad (300 rpm) de los cilindros que componen el trozador.

Hacemos notar en este estudio la influencia geometrica del cilindro y la cuchilla en los procesos de corte y tiro del tallo por el trozador.

Los datos suministrados por este estudio pueden ayudar a determinar con exactitud las caracteristicas de funcionamiento del trozador y pudieron contribuir al mejoramiento de las normas de diseño existentes haciendo asi posible la modernizacion de este aditamento.

GREEN CANE VS. BURNED CANE HARVEST COMPARISONS, 1978-79

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Santa Rosa, Texas

ABSTRACT

In compliance with the Texas Air Quality Control Board Order for the Co-op to search for harvesting alternatives to burning, CLAAS 1400 harvesters were operated and evaluated under actual production conditions in 812 green hectares and 3687 burned hectares. In comparison with burned cane, the green cane sustained a 7.41% sugar recovery loss and increased production costs 9.2% by reducing harvester, in field transport, trucking and milling efficiencies. Vegetative material left after harvesting in green fields was 2.37 times than that left in burned fields. This constituted a major problem for subsequent farming operations.

INTRODUCTION

Four operational factors allowed the Co-op to gather valuable green and burned harvest information during the 1978-79 season without resorting to special harvest trials.

The first factor was the purchase of 20 German-manufactured CLAAS 1400 cane harvesters. These high capacity, high performance machines were purchased in part because of their ability to cut and clean non-burned sugarcane. The economics of doing so profitably were part of this comparison study.

Second, the harvesting scheduled called for the harvest of fields of early and mid-season maturing varieties estimated to yield 67 net tons cane per hectare or less. The strategy was to harvest lighter tonnage fields early thereby giving heavier tonnage fields more time to mature and accumulate sucrose.

Third, from the start of harvesting on November 6 through December 31, there were 18 days when atmospheric conditions were such that the Co-op was not legal to burn under the Texas Air Quality Control Board Order. On five other days, the Co-op received variances for certain weather factors, but sometimes late in the afternoon before which time harvest of burned cane had been completed and green cane harvest started.

Fourth, the factory, because of various mechanical problems, did not grind at the rated capacity of 8727 tons per day.

These four factors when combined meant that the field department had light-tonnage, green and burned cane fields to harvest, suitable machines to do so, and were under only moderate pressure to sustain cane deliveries to the factory during periods when green cane was being harvested.

All the green cane harvest occurred before December 16 which was one week after a serious freeze desiccated all cane tops in the areas being harvested. It took one week for the frozen leaf tissue to fully dry out. Burned cane fields used for comparison are therefore broken into 2 categories: those harvested before December 16 and those after. This is significant because desiccated cane tops burn considerably better than green cane tops and, even unburned, will weigh less because of the moisture lost after cell rupturing.

RESULTS AND DISCUSSION

The nature of the cane

The cane was approximately 1 year in age. Nearly all green harvested cane was erect. The only exceptions were minor acreage in some unusually high productive soil areas. Twenty-five percent of the burned cane was estimated to be lodged. Lodging contributes to scrap losses. Scrap is the millable cane left in the field upon completion of mechanical harvesting. Burning contributes to cane lodging in several ways. The heat of the fire may sear the stalk rind to the extent that the stalk's rigidity is reduced; it becomes limp and sags under its own weight. Trash itself may be so tangled that it props some stalks which otherwise would start to become recumbent. Burning, when it removes trash, allows such stalks to fall outward from the stool. A mechanical harvester often has difficulty picking up lodged cane as the stalks may fall aside and beneath the basecutter discs and blades which are so low in the interrow that the croplifters on the machine do not pick them up. On the harvester, the separation knife which severes cane leaning over from the adjacent row may also drop pieces of cane so that they are never picked up by the advancing machine. This means that scrap loss differences between green cane harvesting and heavily lodged burned cane may, to some extent, be minimized in comparison to the difference observed in green cane and erect burned cane.

Another factor contributing to scrap is the expertise of the operators and the variable conditions encountered which, in the beginning, placed them low on the learning curve with experience in operating and adjusting the harvesters for green cane conditions. The volume of certain kinds of scrap in heavier cane can be reduced.

The effects of burning

The comparative results between trash delivered to the mill from green cane and from burned cane were at first surprising until an explanation was found. The trash in milled cane from over 648 ha of green cane averaged 11.99% by weight. From 602 ha of cane burned before the freeze of December 9, the trash averaged 11.08%, and from 603 ha of cane burned after the freeze, the trash averaged 7.66%. The overall burned trash averaged 9.37%.

At first glance, the difference between green cane and burned cane before the freeze appears too modest. It is not, when one considers the circumstances. By weight, cane trash is 38.6% dry and older dehydrated leaves still adhering to the stalk and 61.4% green material which consists of approximately 10 green leaves and the whorl or spindle of tightly bundled leaves which have yet to emerge from above the growing point.

On this season, no desiccant material (usually Paraquat or Gramoxone at 1.2 l/ha) was applied on any cane. As a result, cane that was burned before the freeze had a high moisture content in its tops. Burning destroyed most dry trash and partially dehydrated tops of this type of cane. It also caused subsequent lodging in parts of some fields. As a result, harvester toppers were unable to top vegetative material which is proportionately higher in weight than other trash. On the other hand, harvesters operating in green cane which mostly remained erect were able to top a large percentage of cane. In any case, the differences in trash between the two types were minimized beyond the point of expectation although the difference in favor of burned cane was still nearly 2%.

With cane burned after the freeze, the trash levels were considerably lower. This cane had thoroughly dehydrated tops which both burned well, withered through cell rupturing and light in weight even if they escaped topping and were deposited into the container. This type of cane equates with desiccant treated cane.

Scrap in the field

Representative scrap samples were collected from .0005 ha size plots in 649 green harvested hectares and 1205 burned hectares. The nature of the scrap was further categorized to pinpoint the reason why it was created during the harvesting process. Loose scrap is defined as stalk pieces which are severed from the stool but never passed through the harvester. These stalks may be cut by the basecutter blades or by the parting knife which separate cane leaning from one cane row into the adjacent one. High cut scrap is still connected to the root piece, but by virtue of being cut too high or knocked down and run over, it is never severed from the stool. Top scrap is that millable cane left in the field when the harvester tops the cane at a point below the growing apex. Side growth scrap is that cane which is never picked up by the harvester or even severed because it is growing out of the side of the cane row rather than the top. Billet scrap is a piece of cane which

have been cut by the machine into billets only to be lost through droppage between the harvester and accompanying trailer from some point in the harvester's conveying process or extracted with trash material in the first or second stage of the harvester's cleaning devices.

Adjusted scrap

Scrap samples were collected after the harvesting equipment has left the area free from traffic. By this time, both harvester and infield hauling equipment have run over the material and smashed it. With the subsequent loss of juice, the scrap weights of the remaining material do not adequately reflect true losses. For this reason, an adjustment was made to scarp weights to bring them back to the equivalent weights of standing cane. Last season's work provided two correction factors. For green cane, it is X 1.64; for burned cane X 1.57.

Tonnage and scrap compilation

Table 1 gives the actual harvest averages for the treatments and acres indicated. The first thing evident is that the harvest of green cane produced upwards was 25.5% (uncorrected) to 31.5% (corrected) more scrap than burned cane or 8.44% to 10.23% increase in scrap. The starting tonnages of vegetative material were comparable as will be shown later.

These scrap figures have a high probability of being both representative and correct and is affirmed by comparing actual net tons per acre recovered + scrap tonnages with the pre-season estimates per acre for the applicable fields. The green cane without scrap falls nearly 21% below estimate. With scrap added back, it closely approximates original estimates. For burned cane with lower scrap losses, the actual is very close to estimate. In fact, the addition of scrap throws them on the high side which may mean that scrap in burned fields was slightly overestimated. One may also speculate that the standing burned cane weights increased due to moisture uptake caused by osmosis and/or capillary action as indicated by the lower bulk of burned cane.

The nature of the scrap

The various categories of scrap were defined previously. Table 2 shows that scrap produced by burning before and after the freeze are nearly identical in composition. When their percentages are applied to the corrected scrap averages compiled for the two treatments, the differences are portrayed in terms of tonnage. Table 3 presents this data. Because the initial starting cane tonnage for the burned cane was higher than for the green cane, the differences shown in Table 3 are not as large as they could be with equal starting tonnages. Table 4 presents the tonnages when both green and burned cane are adjusted to the same initial starting tonnage of 80.65 net tons cane per hectare.

A clearer picture now emerges. It shows that in all categories, green cane

scrap is increased versus burned cane scrap. In terms of tonnage, the major increase is the billet cane category. This increased loss is predominantly attributed to three factors. The first factor is loss through the primary trash cleaning system. In order to reduce leafy trash to acceptable levels, the cleaning system is adjusted to a point where trash extraction will be maximized while at the same time, cane extraction will be minimized. This is not a fine line by any stretch of the imagination, but more or less a compromise based on the machine's integral design. The second factor involves overruns due to operator error. Harvesters cutting in green cane are more subject to choking. When this occurs, the operator either stops or slows the machine until the choke clears itself or he manually clears it. The third factor involves billetted cane being dropped from other points on the machine. Frequently, balled up trash from green cane is so heavy that it escapes the primary extraction mechanisms. Then, it is propelled up the secondary elevator at which time, cut cane pieces may fall over the sides of the elevator because the excess mass of material is too much for the elevator to contain. Jams in the conveying system are often manually cleared. This material must also be discarded on the ground.

In terms of percentage, the greatest scrap difference between burned and green cane is that cane left in topped material. Operators top green cane slightly lower than burned cane in an effort to reduce trash content. Considering the fact that about 25% of the burned cane was lodged and consequently untopped, this difference is accentuated.

It is most significant to note in Table 4 that from an average yielding field (nearly 80.8 net tons cane per ha), the scrap in a green harvested field was 8.24 tons or nearly 60% of 10.21 percentage points more than that left in a burned field.

Sugar in the bag

Table 5 lists juice analyses for various green and burned fields harvested during the same weekly period. The results generally reaffirm previous information that green cane has better juice quality than burned cane. Because we were dealing with a wide range of harvest, weather and cultural-related conditions which could also create differences and paired or split plot comparisons were not obtained. The statistical significance of these juice differences cannot be calculated.

Table 6 shows sugar yield calculations based on the government's ASCS formula used by the mill. Applying the formula to the actual tons cane and actual trash results, we note that green cane has a 10.18% yield of sugar per ton of net cane while burned cane has a 9.61% yield. Even with better quality however, the loss of tonnage so exceeds the benefit of juice improvement that the green cane averages a 1.50 ton sugar per hectare loss.

The second part of Table 6 is a similar yield calculation, but the assumption used here is that both green and burned cane fields started with the same initial net tons cane per hectare. From this is deducted the corrected scrap percentages shown

TABLE 1. Tonnage and scrap yield averages for burned and green harvested field

		-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-
		Hectares Harvested	Estimated Net Tons Cane/Ha	Harvested Net Tons Cane/Ha	Actual Scrap Tons/Ha	Corrected Scrap Tons/Ha	Estimated Starting Net Tons Cane/Ha (Actual NTC + Scrap)	Scrap as a % of Column 6 (4 or 5 ÷ 6)	Harvested NTCH as a % of Est. NTCH (3 ÷ 2)	Harvested NTCH + Scrap as a % of NTCH (4 or 5 ÷ 2)
Green Cane - Before Scrap Correction		649.21	60.80	48.25	11.07		59.32	18.66	79.36	97.56
Green Cane -- After Scrap Correction		649.21	60.80	48.25		18.16	66.41	27.35	79.36	109.19
Burned Cane (Before Freeze)	Before Correction	601.46	72.25	65.76	9.32		75.08	12.41	91.02	103.92
Burned Cane (Before Freeze)	After Correction	601.46	72.25	65.76		14.64	80.40	18.21	91.02	111.28
Burned Cane (After Freeze)	Before Correction	601.46	68.37	67.92	8.31		76.23	10.90	99.34	111.49
Burned Cane (After Freeze)	After Correction	601.46	68.37	67.92		13.04	80.96	16.00	99.34	118.42
Burned Cane (Combined)	Before Correction	1,204.66	70.30	66.84	8.80		75.64	11.64	95.08	107.60
Burned Cane (Combined)	After Correction	1,204.66	70.30	66.84		13.81	80.65	17.12	95.08	114.72

TABLE 2. Green and burned cane scrap broken down into components as % of total

Scrap Component	Burned Before Freeze	Burned After Freeze	Burned Combined	Green Cane
Loose	30.6	33.6	32.1	24.5
High Cut	17.8	16.1	16.9	11.0
Low Topped	7.6	8.2	7.9	11.1
Side Growth	13.0	14.0	13.5	14.0
Billet (Overrun-Extract)	30.9	28.1	29.6	38.4
	100.0	100.0	100.0	100.0

TABLE 3. Green and burned cane scrap broken down into components by actual tonnage

Scrap Component	Burned Combined	Green	Difference	Difference as a % of burned
Loose	4.45	4.45	-0-	-0-
High Cut	2.34	2.00	-.34	-14.5
Low Topped	1.08	2.02	+.94	+87.0
Side Growth	1.86	2.54	+.68	+36.6
Billet (Overrun-Extract)	4.09	7.16	+3.07	+75.1
	13.82	18.17	+4.35	+31.5%

in Table 1. This procedure eliminates any contention that tonnages for the two treatments were unequal to begin with. In this case, green cane sustains a .43 ton sugar per hectare loss from burned cane. At $319 a ton return for sugar, this loss alone is worth $137.17 a hectare or a 7.1% reduction in possible returns from burned cane.

Trash removal

Extraneous matter is any material delivered to the mill other than millable cane. This definition encompasses green and dried leaf material, burned leaf material, roots and soil. In last season's study, it was reported that in unburned

TABLE 4. Green and burned cane scrap from same initial base broken down into components by actual tonnage

Scrap Component	Burned Combined	Green	Difference	Difference as a % of Burned
Loose	4.45	5.41	+ .96	+ 21.6
High Cut	2.34	2.42	.08	+ 3.4
Low Topped	1.08	2.45	+1.37	+126.8
Side Growth	1.86	3.08	+1.22	+ 65.6
Billet (Overrun-Extract)	4.09	8.69	+4.60	+112.5
	13.82	22.05	+8.23	+ 59.6

fields, 30.4% by weight of the starting above ground vegetative material was extraneous matter. Applying this figure to the corrected starting net tons cane per acre, Table 1 gives an approximation of gross starting vegetative matter.

For *green cane* this is:

66.41 NTCH + .304 X = X

X = 95.42 tons start vegetative matter

For *burned cane* this is:

80.65 NTCH + .304 X = X

X = 115.88 tons start vegetative matter

With 11.99% trash, the harvesters produced for the mill 54.86 gross tons cane per ha in green cane; with 9.37% trash, 73.78 GTCH in burned cane. The differences between delivered gross tons and starting vegetative matter are the tonnages which were removed or destroyed by burning or during the harvesting process.

For *green cane* delivered to the mill:

95.42 - 48.28 NTCH - 6.58 tons trash/ha = 40.56 tons left in field.

Of this total, 18.13 tons were scrap meaning the machine also extracted an additional 22.43 tons trash.

For *burned cane* delivered to the mill, the calculation is slightly different.

115.88 - 66.86 NTCH - 6.92 tons trash/ha = 42.10 tons possibly left in field.

We know that the total beginning extraneous matter was 30.4% x 115.88 = 35.23 tons. Last season's work showed that a good burn removed 71% of this

TABLE 5. First crusher juice analyses for green and burned harvested during the same weekly periods

GREEN				BURNED			
No. Samples	BRIX	POL	PURITY	No. Samples	BRIX	POL	PURITY
			VARIETY				
			CP65-357				
68	16.06	14.00	87.17	50	16.88	14.52	86.02
9	16.96	14.62	86.20	130	16.52	14.17	85.77
5	16.96	14.82	87.38	137	16.84	14.41	85.57
Sub Average 82	16.96	14.12	87.11	317	16.72	14.33	85.71
			CP52-68				
128	16.94	14.89	87.90	48	17.30	14.80	85.55
79	16.99	14.56	85.69	52	16.19	13.97	86.29
10	18.12	15.72	86.75	111	17.25	14.86	86.14
20	17.08	14.81	86.71	74	16.17	13.54	83.74
Sub Average 237	17.02	14.81	87.02	285	16.78	14.34	85.46
			CP61-37				
93	16.04	14.05	87.59	77	16.42	14.32	87.21
43	16.55	14.18	85.68	182	15.67	13.41	85.58
25	17.24	14.93	86.60	146	16.48	14.17	85.98
62	16.33	14.15	86.65	135	15.72	13.59	86.45
Sub Average 223	16.35	14.20	86.85	540	16.01	13.79	86.13
			NCo310				
17	17.00	14.68	86.35	2	16.40	13.99	85.30
15	17.25	14.55	84.35	137	17.05	14.75	86.51
9	17.76	15.36	86.49	12	16.42	14.30	87.09
Sub Average 41	17.25	14.78	85.68	151	16.99	14.70	86.52
			Grand Average all Varieties				
583	16.67	14.48	86.86	1293	16.47	14.15	85.91

TABLE 6. Sugar calculation

Yield figure for actual TCH averages of green and burned cane.

GREEN

		NORMAL JUICE		
NET TCH	TRASH%	BRIX	POL	PURITY
48.25	11.19	16.18	13.78	85.16

Sugar (Raw Value – RV) Recovered

$$\text{Per Net Ton} = \frac{0.7633 \times 0.8650 \times 2200 \times 0.1378 \times (1.4 - 85.16) \times 1.05}{\dfrac{48.25}{0.98264 \times 54.83}}$$

$$\frac{193.66}{0.8647} = 223.9 \text{ or } 10.18\% \text{ yield}$$

BURNED

		NORMAL JUICE		
NET TCH	TRASH%	BRIX	POL	PURITY
66.84	9.37	15.99	13.47	84.22

$$R_V = \frac{0.7633 \times 0.8650 \times 2200 \times 0.1347 \, (1.4 - 84.22) \times 1.04}{\dfrac{66.84}{0.98264 \times 73.76}}$$

$$\frac{188.24}{0.8905} = 211.39 \text{ or } 9.61\% \text{ yield}$$

TSH RECOVERED

Green	Burned
$0.1018 \times 48.25 = 4.91$	$0.0961 \times 66.84 = 6.42$

Yield figure for same starting tonnages green and burned less actual scrap loss percents and actual trash for each.

Start with 75.98 NTCH – The weighted average of corrected green and burned

Green

Start 75.98 NTCH $- 0.2735 \times 75.98 = 55.20$ NTCH with 11.99% trash

scrap

$$R_V = \frac{193}{0.98264 \times \dfrac{55.20}{62.72}} = \frac{193.66}{0.8648} = 223.9$$

Burned

Start 75.98 NTCH − 0.1712 x 75.98 = 62.98

scrap

$$R_v = \frac{188.24}{0.98264 \times \frac{62.98}{69.49}} = \frac{188.24}{0.8905} = 211.39$$

TSH Recovered

Green	Burned
0.1018 x 55.20 = 5.62	0.0961 x 62.98 = 6.05

material, 71% x 35.23 = 25.01 removed by fire before harvest. Therefore, 10.22 tons trash/ha were left before harvest. Of this, 6.92 tons were delivered to the mill leaving 3.24 tons removed by machine cleaning. Table 7 shows a short balance sheet setting forth the material disposition.

What is interesting is that the initial tonnage of material for harvesters to handle is nearly similar for both burned and green fields (90.85 for burned; 95.42 for green). While the initial totals are quite comparable, it will be seen in the next section what affects the composition of each had on harvester efficiencies.

Harvesting performance

The machines harvesting green cane were handling 14.23 tons per ha or 17.6% less millable cane, but 18.79 tons per ha or 84% more trash than the harvesters operating in burned cane.

Operator visibility is obscured by trash which also causes chokes within the equipment, wraps around croplifters, balls up in front of the machine which necessitates stopping and backing in order to be able to engulf it in smaller pieces, slows forward motion of the machine to accommodate pickup without a bulldozing effect, constant readjustment of basecutter blades which are obscured and more frequent stops to remove trash where it builds up and reduces the cross-sectional cleaning area.

The result, of course, is fewer tons cut per harvester operating hour. The operating data shows the following performance:

	burned	green	difference	difference as a %
gross tons cut/harvester hour	32.58	23.00	- 9.58	- 29.4
net tons cut/harvester hour	29.52	20.24	- 9.28	- 31.4

In order to produce the same amount of cane for delivery to the mill during the

TABLE 7. Vegetative matter balance per hectare

	BURNED		GREEN	
	Tons	As a % Of Start	Tons	As a % Of Start
Start Total Vegetative Matter	115.88	100	25.42	100
Extraneous Matter	35.23	30.4	29.01	30.4
Millable Cane	80.65	69.6	66.41	69.6
Net Cane Delivered To Mill	66.86	57.7	48.28	50.6
Scrap Left In Field	13.79	11.9	18.13	19.0
Trash Delivered To Mill	6.95	6.0	6.58	6.9
Trash Destroyed By Fire	25.03	21.6	———	———
Trash Left In Field	3.24	2.8	22.42	23.5
Total Vegetative Matter Left In Field Before Being Run Over	17.15	14.8	40.55	42.5
Total Vegetative Matter Left In Field After Harvesting Is Complete	12.10	10.44	33.50	35.11
Starting Tonnage For Harvesters	90.85	78.4	95.42	100

Composition of Harvested Material

	BURNED		GREEN	
	Tons	As a % Of Start	Tons	As a % Of Start
Millable Cane	80.65	88.76	66.41	60.60
Trash	10.22	11.24	29.01	30.40
	90.87	100.00	95.42	100.00

Composition of Delivered Material

	BURNED		GREEN	
	Tons	As a % Of Start	Tons	As a % Of Start
Millable Cane	66.86	90.63	48.28	88.01
Trash	6.92	9.37	6.58	11.99
	73.78	100.00	54.86	100.00

same time as taken for burned cane, the Co-op would need 30% more harvesters or the equivalent in harvester availability for green cane.

Hours of operator maintenance were accumulated for harvesters in both green and burned cane fields. Operator maintenance consists of washing, cleaning, clearing major chokes, checking, changing basecutter blades and helping the mechanic with repairs. It does not include clearing minor chokes which fall in the realm of operating.

The results for each 100 tons of gross cane or 10 ha harvested were:

(maintenance hours)	green	burned	difference	difference as a %
hours/100 tons of cane	3.30	2.31	- 0.99	- 42.8
hours/10 hectares of cane	180.3	160.6	- 19.7	- 12.3

Maintenance time appears to be directly proportional to the number of tons passing through the machine. As an example:

on an average, it took 4.34 hours to cut 100 tons of green cane and
3.07 hours to cut 100 tons of burned cane.

When the maintenance figures as noted above are divided by the appropriate hours to cut 100 tons, the result is as follows:

maintenance hours are 75.9% of cut hours for green cane and
75.3% of cut hours for burned cane.

Reducing maintenance hours by reducing extraneous matter passing through the machine is a direct relationship.

Effect of trash on transportation and milling

An average truckload of burned cane weighed 16.94 tared tons while green cane averaged 15.76 tons. The 1.18-tons/truckload is a 6.97% decrease. To sustain the same mill delivery tonnage as in burned cane would require a 6.97% increase in trucking availability. This is equivalent to an increase of four trucks to the present fleet.

Since the capacity of the mill as an extraction plant is governed by the fiber handled per unit of time, added fiber would have the effect of reducing the production capacity. A test conducted at the W.R. Cowley Sugar House this season showed that a 1% increase in trash content of gross cane reduced gross tons ground per hour by approximately 3%. A difference of 2.62 percentage points in trash content between green and burned cane was obtained in this study. This additional trash would reduce the 363.3 tons/hour (8727 tons/day) milling rate by 7.86% or 28.58 tons/hour (686 tons/day). A difference of this magnitude extra-

polated for the whole campaign would increase the mill grinding operations by 12 days.

Ratoon cultivation

Vegetative matter left in burned fields before being run over averaged 17.15 tons per acre while for green harvested fields it averaged 40.56 tons. This latter total which is two-thirds leafy matter will impede any subsequent cultivation operations. At present, no economical and mechanical method for its removal is in use. This mass of material requires burning for its removal. Subsoiling, off-barring, fertilizer injection, and irrigation are impossible to perform without removal of this material. Alternative cultural practices would have to be developed.

Frozen unburned cane

On several occasions the Co-op was unable to burn frozen fields because of weather conditions. When attempts were made to harvest this type of material, harvesting was unsuccessful. The freeze desiccated all the green leaf material, leaving mainly fiber. Chopper mechanisms on the harvesters had difficulty in cleanly slicing this type of vegetative material entering the machine. The stringy fibrous leaves and tops also tend to wrap around moving parts such as croplifters, sprockets, elevator flights, etc. This problem was compounded when light rain, drizzle or morning dew was present. This moisture caused the leaves to stick as wet paper does. They would adhere to almost any surface on the harvester, but especially to the cleaning sections where buildup would reduce effective air passage. In addition, the leaf material when dry presents a fire hazard as it accumulated between moving parts, belts, engine exhaust or other hot parts of the harvester. Harvesting of unburned cane other than "real green" cane appears out of question.

Economic impact of green cane harvest

Table 8 is a balance sheet showing both additional costs and savings to be made with green cane harvest. This table is based on the assumption that 75.98 net tons cane per ha (the weighted average of corrected green and burned cane harvested through December 31, 1979) was the starting tonnage for both treatments. The costs are derived from actual costs for the 1978-79 campaign through December 31. Some fixed costs for several activities are not included.

Except for the elimination of burning costs and the reductions to be made in gross tons cane delivered (because more starting cane is left in the field), green cane costs rise considerably.

For those activities listed, the total cost to date through December 31 per ton of cane is $18.77. The increased cost of handling green cane is $1.73. This is a 9.2% increase. The increased loss of sugar in scrap remains the biggest single factor. At $5.61 per ton gross cane ground, it is nearly 3 times the increase in variable production cost. This increase does not take into account additional wear and tear

TABLE 8. Balance sheet comparing burned and green cane production costs to produce equivalent amount of sugar

Percent Change (Green/Burned)		COST PER TON (Rounded to 2 Places) Green	Burned	Change In Cost Per Ton
– 100.00%	Cane Burning	–	0.06	(0.06)
+ 31.40	Harvesting	3.18	2.42	0.76
+ 27.60	Infield Transport	1.26	0.99	0.27
+ 6.97	Cane Transfer	0.46	0.43	0.03
+ 31.40	General Labor & Labor Transport	0.59	0.45	0.14
+ 43.10	Equipment Maintenance	0.13	0.09	0.04
+ 6.97	Hauling & Dispatching	2.38	2.22	0.16
+ 7.86	Factory	13.07	12.11	0.96
	SUB-TOTAL	21.07	18.77	2.30

Because the juice quality of green cane is slightly better than burned cane, its cane ratio is lower resulting in a partial recovery:

– 2.70%	0.27 Green Ton Less Needed to Produce One Ton Sugar @ 21.07	(.57)
	Net Change in variable production cost	1.73

$$\frac{1.73}{18.77} = 9.2\% \text{ Additional Production Cost/Ton For Green Cane}$$

If additional sugar loss in scarp in green cane above that normally lost in burned cane is considered, then the difference is:

– 88.9	.0176 Ton Additional Sugar Loss @ $319/Ton For Each Ton Gross Green Cane Ground	–5.61
	Overall difference green vs. burned for each gross green ton ground:	
	5.61 + 1.73 = 7.34	–6.22

on equipment, nor expenses which the farmer must incur for trash removal after harvest.

Lastly, these costs reflect only operability in the tonnages actually cut. It is not known if the harvesters could perform at the same rates in heavier tonnage fields, i.e., those approaching 135 or more gross tons vegetative matter per hectare.

SUMMARY

1. Trash delivered from green harvested fields averaged 11.99% of total material. This is 2.62 percentage points more than in burned cane. Trash in green cane reduced trucking densities by 6.97% or .45 ton per 1% increase in extraneous matter.

2. Scrap for green cane was 27.3% of initial millable cane compared to 17.12% for burned cane.

3. Starting from the same net cane base (75.98), green cane harvest would sustain a recovery loss of .43 tons sugar per ha compared to burned cane although the quality of juice from green cane is superior. The sugar loss has a value of $137.17 per ha.

4. Handling of .38% more volume of material in green cane caused a 31.4% reduction in the harvester efficiency. Maintenance time rose proportionally to the excess tonnage handled.

5. Vegetative material left in unburned fields is 2.37 times that left in burned fields. Amounts averaging 40.56 tons/ha would constitute a serious problem for subsequent farm cultivation activities.

6. Harvesters are unable to perform effectively in frozen, unburned cane.

7. Handling green cane could increase operating costs by 9.2% in measurable areas and in addition shorten equipment life to a degree not as yet formulated. Sugar lost in green cane scrap above and beyond that lost in burned cane scrap amounts to $5.10 per gross ton green cane ground.

8. With the present return for sugar, green cane harvest operations are not economically justifiable, and they still await testing in fields with higher initial tonnage.

9. Increased experience in green cane by harvester operators may reduce scrap losses to a more acceptable level.

10. The use this season of harvesters with cane-cutting capabilities for green cane and poorly burned cane was a real advantage over the older machines which under the 1977-78 season would have forced us to burn cane 4 to 5 days ahead of harvest or shut the mill down due to no cane or low cane supply.

COMPARACION ENTRE COSECHA DE CAÑA VERDE Y CAÑA QUEMADA 1978-79

Norman Rozeff y H. R. Crawford, Jr.

RESUMEN

De acuerdo con la orden de la Junta de Control y Calidad de Aire de Texas, para la Cooperativa investigar metodos de cosecha y presentar alternativas que eliminen la quema, combinadas CLAAS 1400 fueron operadas y evaluadas bajo condiciones actuales de produccion en 812 hectareas de caña verde y 3687 hectareas de caña quemada. Los datos son presentados en varias tablas. En comparacion con caña quemada, la caña verde sostuvo un 7.41% de perdida en la recuperacion de azúcar, y un incremento en costo de produccion de 9.2% reduciendo la eficiencia de cosecha, transporte dentro del campo, acarreo y molienda. Material vegetativo que quedó en el campo despues de la cosecha fue 2.37 veces mayor en campos de caña verde que en aquellos campos quemados. Esto creó un problema significativo para las operaciones agricolas subsiguientes.

CANE LOSS IN FIELDS HARVESTED WITH PUSH-RAKE SYSTEM

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ABSTRACT

The study was conducted to determine the amount of millable cane existing in the field before and after the "braceo" (the last manual collection) and the amount of cane that is possible to pick up during the operation.

Before the "braceo" there is an average of 3.8 ton/ha of millable cane or 1.95% of the net yield. The average loss of millable cane is about 2.7 tons/ha or 1.47% of yield. During the "braceo" operation it was possible to pick up an average of 1.065 tons/ha. Forty-five % of the collected cane (before or after the "braceo") was crushed by the harvesting machinery. There is a directly proportional correlation of gross and net yield with amount of cane that is in the field before the "braceo". Quality variables show that cane crushed by the harvesting machinery loses quality in comparison with the cane that is not crushed.

INTRODUCTION

In Peru sugarcane is grown in about 85,000 ha, 50% of which use the mechanical cutting system called "Push-Rake". The rest is cut by hand using rotary machine cutters which are still at an experimental stage.

Sugarcane harvesting in the Agricultural Cooperative Casa Grande represents about 25% of the total cultivation of this type in the whole country and 45% of the total sugarcane that is cut mechanically. In this cooperative, harvesting is performed by using the Push-Rake system for both cutting and piling up cane, both operations carried out simultaneously. In this system as well as in any other used by cane industry, losses of millable cane are found at several points (Lage[6]).

Considering the two most important tendencies existing within mechanization of sugarcane harvesting, Push-Rake and rotative, it can be noticed that sugarcane losses have more often been studied in harvestings with rotative cutters than in harvestings with Push-Rake system. Such a situation exists because mechanical harvesting Push-Rake system requires adequate conditions and installations in order to separate extraneous matter carried with cane. Besides, Push-Rake is very often considered as a temporal harvesting means (Smith[7]). However, in some sugarcane

regions such as Peru and Hawaii, the characteristics of sugarcane cultivation as well as its growth habits necessitates the use of mechanical harvesting system, especially for areas whose yields are above 170 t/ha.

In connection with cane loss, Lage[6] said that it is necessary that the total losses of a system should not be higher than 5%, and that losses of 4% with Push-Rake system and 5.5% with harvesting rotary system are acceptable and reachable loss levels. The latter loss is distributed as follows: 1.5% during cane cutting; 0.5 % during cutting of sugarcane top; 1.5% during ventilation; 0.5% during transhipment; and 1.5% at the storing center.

Cerrizuela[3] studied cane losses using several rotary harvesting machines in fields of 60 to 80 t/ha. He found losses of 4.4% and 6.8% when two types of integral harvesters were used; 4.7% when a combination of cutter and piler was used; and 1.3% when a combination of cutter and piler was used while the cutting off and piling were made by hand, loading being mechanical. On the other hand, Furlani Neto[5] said that increases of advance speed of harvesters raised the loss of cane in the field. He found that in a field of 87 t/ha the average loss with speed machines is 2.28 t/ha; with regular speed machines 3.24 t/ha; and with high speed machines 4.81 t/ha.

A very important feature of rotary harvesters is the efficient cutting off they can get. This is done by cutting with circular knives or by a pneumatic separation (Cerrizuela[3]). In his study about stripping tools, Brito[2] reported that losses of profitable cane parts during the process of stripping depend on the uniformity of cane height or variation coefficient and the degree of the plant erection; and concluded that on an average a stripper works efficiently in fields with a variation coefficient of $V < 20\%$. This machine gets an efficient elimination of sugar cane tops of 45% with losses of 1.8%. According to Clayton *et al*[4], and Cochran and Clayton (in Cerrizuela[3]), pneumatic separation is not very efficient because specific weight of stalk is almost the same at their lower and upper part. However, Abreau[1] introduced some changes in pneumatic separation system of KTP–1 harvester and increased the efficiency of this system by 22% thereby reducing the total loss to 3%.

The present research intends to evaluate the amount of sugarcane that is left in the field before the "braceo" operation (the last manual collection), the amount of sugarcane that is possible to pick up during the "braceo" operation and the amount of cane that definitely remains in the fields harvested with Push-Rake system.

METHODS AND MATERIALS

The harvesting system in Casa Grande included the following operations:

a. *Preparation of the fields for harvesting* — This includes operations such as levelling of streets, retilling of drains, etc. that allow the harvesting

machine to get into the fields as well as burning.

b. *Simultaneously cutting and piling* — Through the use of transcavators of tires models 988 and 922-B with a Hawaiian model cutter (Push-Rake).

c. *Loading in transportation* — Loading is done mechanically by using hook cranes and a team of three people (gatherers) on trucks (trailers) with two cane carts, each with a capacity of 30 tons.

d. *Chopping ("repique")* — This consists of cutting by hand the canes that remain on the field. These canes are placed across the furrows to pile them up more easily by means of a 950 transcavator equipped with a cutter like instrument. For chopping 2.3 shifts ("tareas") /ha are employed for a quantity of cane in the field that varies between 10 and 15 t/ha.

e. *The "braceo"* — Once chopping is over, some canes still remain on the ground and for this reason a second and last gathering is made by hand. This operation of gathering is called "braceo" and canes gathered in this way were also piled by using a 950 transcavator. For this operation an average of 1.5 shifts ("tareas")/ha are needed.

f. *Data* — Plots for harvesting were chosen randomly. This was done immediately before and after the "braceo" operation. Then in both cases all canes growing in each plot were picked up. Each plot was 720 m^2 containing four furrows each 120 m long and 1.5 m apart. Cane collection was divided into two separate parts: collection performed at the head of the plot where loading took place (the last 8 m) and collection performed in the rest of the plot. The collected stalks were also divided: stalk parts crushed by the machines and complete stalk parts. Total weight, weight per each linear meter and quality analysis were collected separately. Twelve replications were performed before the "braceo" and 13 after this operation.

RESULTS AND DISCUSSION

The results obtained (Table 1) show that the yield of the plots where the repetitions were performed varies between 125 and 330 t/ha for gross yield and between 108 and 288 t/ha for net yield. Net yield (gross yield minus the percentage of extraneous matter) varies between 11% and 15%.

The total amount of canes existing in the field before the "braceo" has a variation rank of 1.610 - 4.583 t/ha with a standard deviation of 0.770 considering the average (3.301 t/ha) or a variation rank of 1.11-2.14% considering the net yield of the field with a standard deviation of 0.28 regarding the average 1.68%. Cane after the "braceo" (cane that is lost) varies from 1.417 to 3.100 t/ha, with a standard deviation of 0.551 considering the average 2.391 t/ha or it varies from 0.49% to 2.02% of net yield with a standard deviation of 0.36 regarding its average

TABLE 1. Gross and net yield and the amounts of cane collected before and after the "braceo"

Replication	Gross Yield t/ha	Net Yield t/ha	Collected cane (t/ha)			% of Net Yield
			Crushed	Not crushed	Total	
			Before the "braceo"			
	Y1	Y2	X1	X2	X3	
1	213	184	1.514	2.028	3.542	1.92
2	258	222	1.694	1.528	3.222	1.45
3	269	232	2.472	2.111	4.583	1.98
4	248	214	2.472	1.402	3.874	1.81
5	202	174	1.125	1.916	3.041	1.75
6	170	145	0.638	0.972	1.610	1.11
7	196	167	1.444	2.133	3.577	2.14
8	175	149	0.778	1.611	2.389	1.60
9	276	241	2.208	2.055	4.263	1.77
10	240	212	0.900	1.876	2.776	1.31
11	229	198	2.110	1.389	3.500	1.77
12	240	208	1.125	2.111	3.236	1.56
Average	226	196	1.540	1.761	3.301	1.68
Standard deviation	—	—	0.625	0.359	0.770	0.28
			After the "braceo"			
1	213	184	1.764	1.319	3.083	1.68
2	233	201	1.278	1.625	2.903	1.44
3	226	195	1.111	1.264	2.375	1.22
4	196	169	0.833	0.930	1.763	1.04
5	238	206	1.625	1.388	3.040	1.48
6	192	165	0.958	1.000	1.958	1.19
7	174	149	0.652	1.000	1.652	1.44
8	208	177	1.289	1.266	2.555	1.44
9	227	193	1.378	1.722	3.100	1.61
10	279	237	1.044	1.711	2.755	1.16
11	330	288	0.389	1.028	1.417	0.49
12	253	220	0.659	1.659	2.311	1.05
13	125	108	0.916	1.263	2.179	2.02
Average	223	192	1.071	1.321	2.391	1.33
Standard deviation	—	—	0.383	0.274	0.551	0.36
Difference of averages			0.470	0.323	0.910	0.38

TABLE 2. Amount of collected cane per 100 m^2 of the zone where loading takes place

Replication	Collected cane kg/100m^2 Crushed	Not crushed	Total	Converted to t/ha
		Before the "braceo"		
1	–	–	–	–
2	–	–	–	–
3	33	54	87	0.580
4	19	65	84	0.560
5	33	35	68	0.454
6	14	36	50	0.333
7	50	56	106	0.707
8	18	46	64	0.427
9	21	40	61	0.407
10	18	89	107	0.714
11	49	44	93	0.620
12	22	43	65	0.434
Average	28	51	78	**0.524**
Standard deviation	12	16	19	**0.125**
		After the "braceo"		
1	54	35	89	0.594
2	52	71	123	0.820
3	12	29	41	0.273
4	46	32	78	0.520
5	19	19	38	0.253
6	10	35	45	0.300
7	7	26	33	0.220
8	29	21	50	0.333
9	19	26	45	0.300
10	25	36	61	0.407
11	10	32	42	0.280
12	11	27	38	0.253
13	12	24	36	0.240
Average	24	32	55	0.369
Standard deviation	16	12	25	0.169
Difference of averages	4	19	23	0.155

**Cane collected in the 667 m^2 that corresponds to a hectare when the field has 120 m long furrows.*

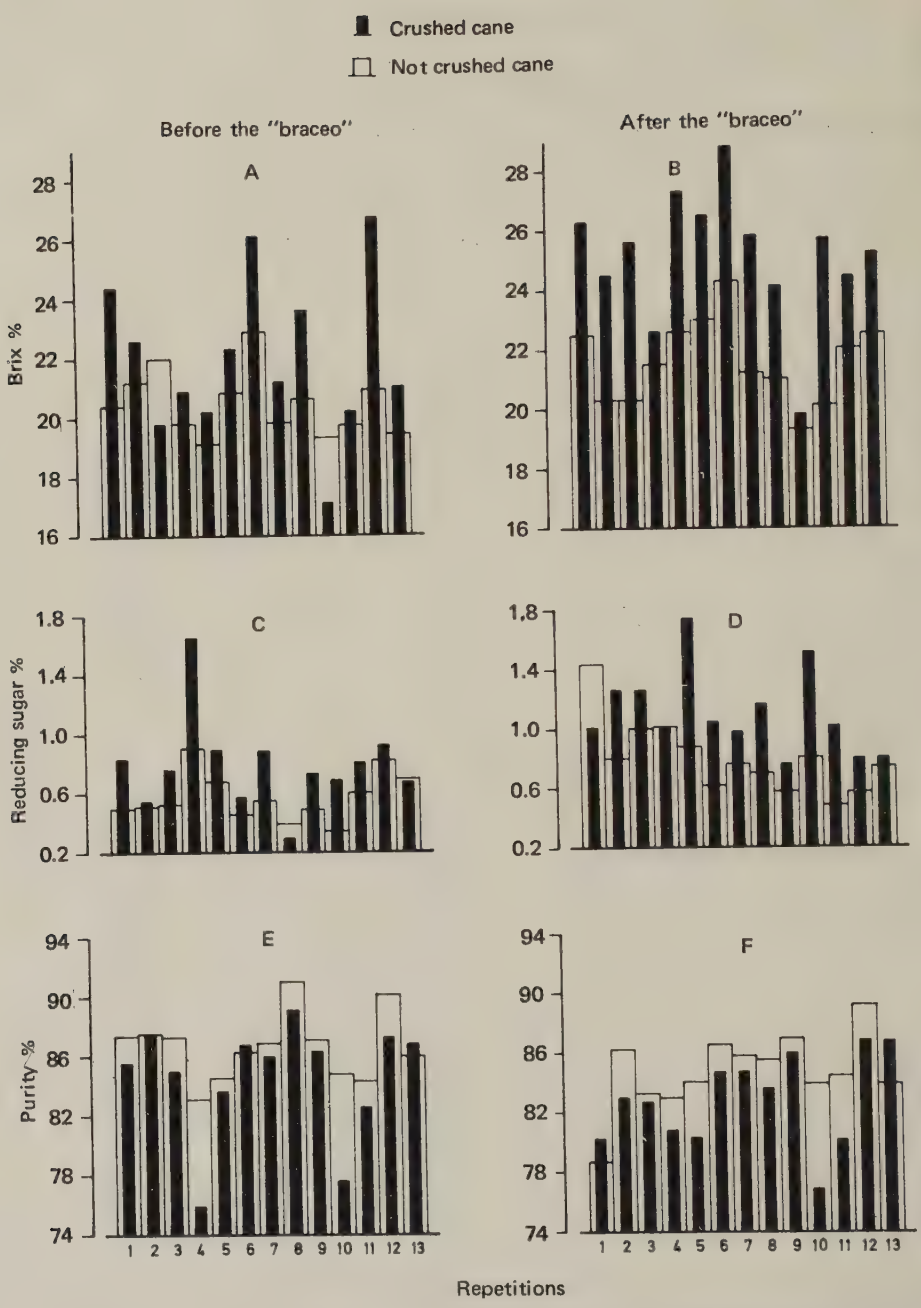

FIGURE 1. Correlation between gross and net yields with collected canes before and after the "braceo"

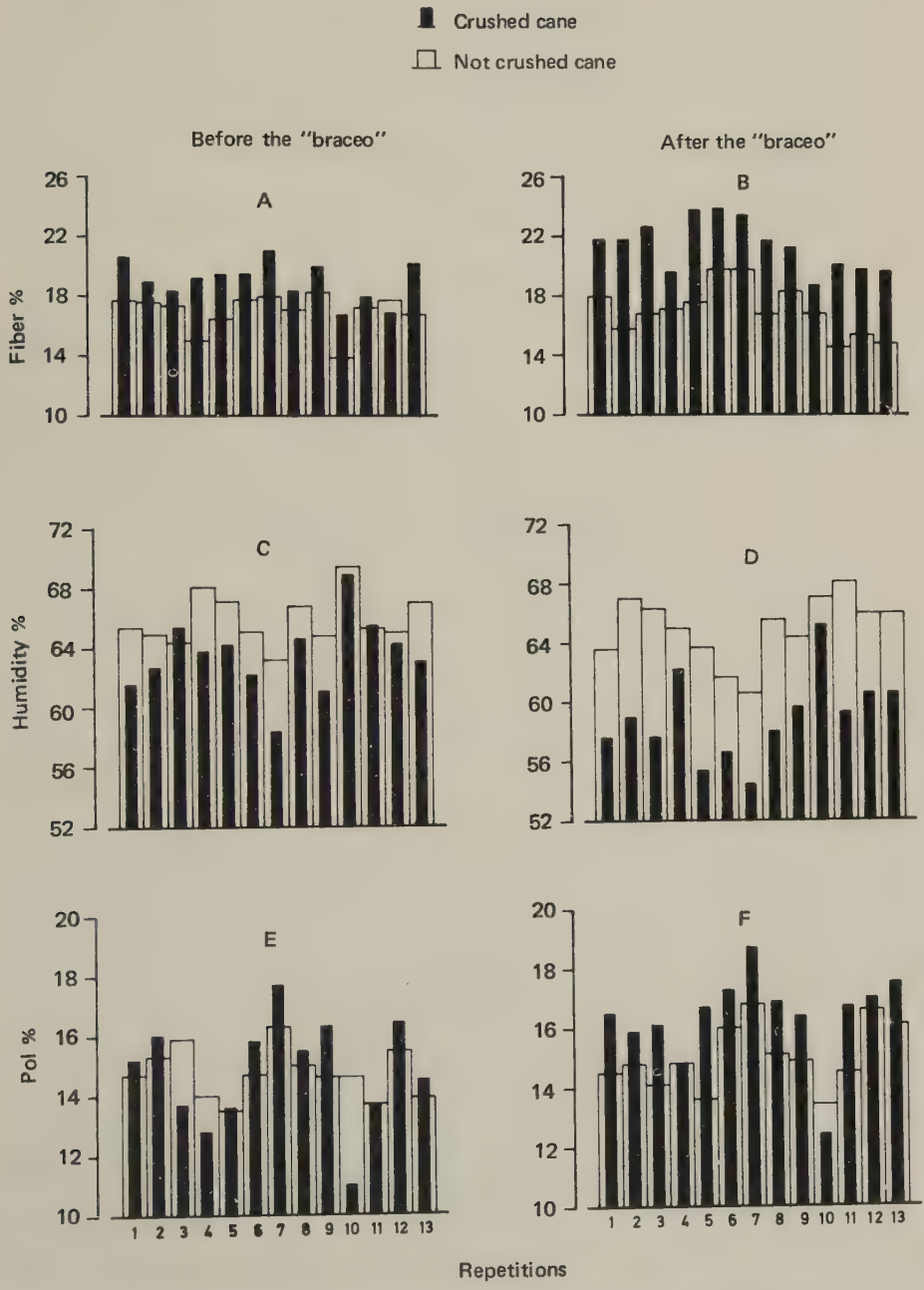

FIGURE 2. Percentages of fiber (A,B), humidity (C,D) and pol (C,F) of crushed cane and not crushed cane collected before and after the "braceo"

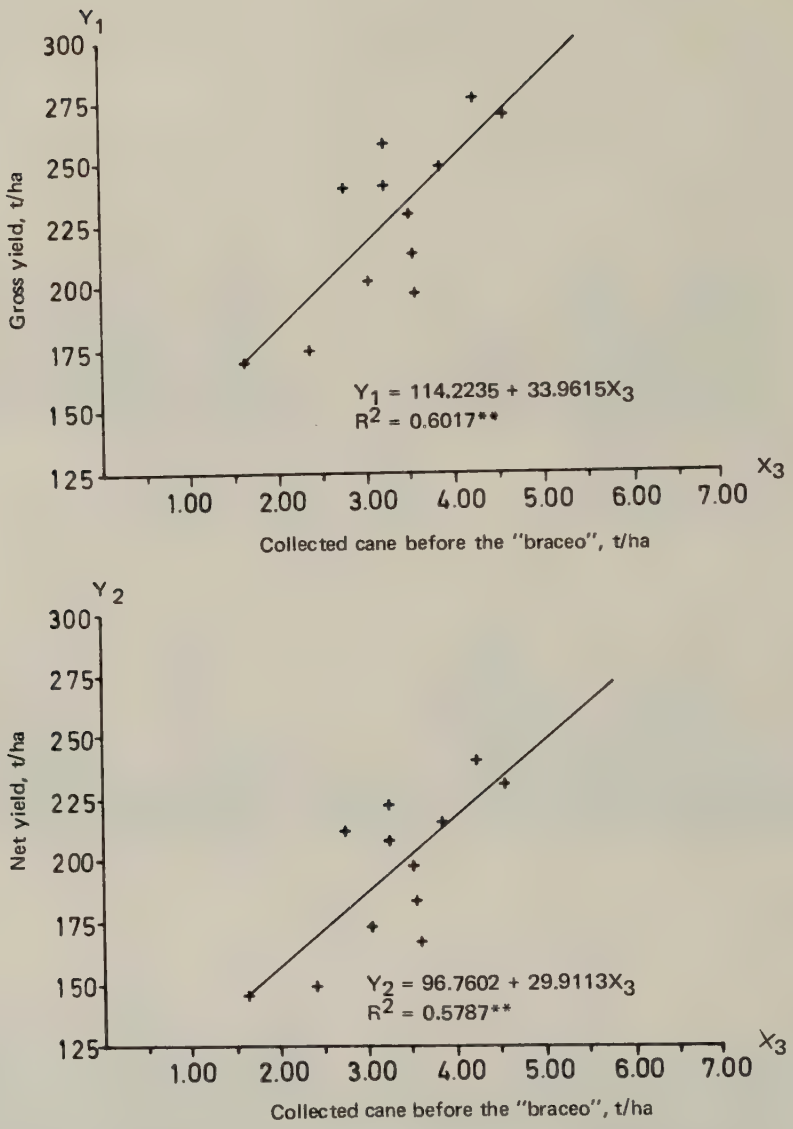

FIGURE 3. Percentages of brix (A,B), reducing sugar and purity (E,F) of crushed and not crushed cane collected before and after the "braceo"

1.33%. Cane crushed by the harvesting machinery used is approximately 50% of the above quantities.

In Table 2, it can be seen that the amount of sugarcane was picked up at the head of the plot (the last 8 m of furrows) where sugarcane was loaded per 100 m^2 extension. It also shows the amount of sugarcane gathered in 667 m^2, an extension

TABLE 3. Average amounts (t/ha) of cane collected in the field before and after the "braceo"

Before the "braceo"	Crushed	Not crushed	Total	%
In the field	1.540	1.761	3.301	1.68
At the head of the plot	0.189	0.335	0.524	0.27
Total	1.729	2.096	3.825	1.95
After the "braceo"				
In the field	1.070	1.321	2.391	1.30
At the end on the plot	0.162	0.207	0.369	0.17
Total	1.232	1.528	2.760	1.47
Difference	0.497	0.568	1.065	0.48

that represents the loading zone corresponding to a hectare, with average furrows of 120 m long. These quantities plus the ones shown in Table 1 give the total amount of sugarcane existing in the field before and after the "braceo" (Table 3).

Table 3 shows the average amount of sugarcane both before and after the "braceo". These results indicate that in the field before the "braceo" there was a total amount of 3.825 t/ha of cane divided into two smaller quantities: 1.729 t/ha (45%) of cane crushed by the machinery and 2.096 t/ha (55%) of cane that was not crushed. After the "braceo" there was a total amount of 2.760 t/ha divided into 1.232 t/ha (45%) and 1.528 (55%), respectively. This amount remains definitely and on an average represents 1.47% of net yield of the field.

The difference represents the amount of sugarcane that was gathered during the "braceo", that is a total amount of 1.065 t/ha divided into 0.497 t/ha (47%) of crushed cane and 0.568 t/ha (53%) of complete cane. Correlations between gross yield (y^1) and net yield (y^2) with the amount of crushed cane, not crushed cane and the total amount picked up in the field before and after the "braceo" were done (Fig. 1). There was a correlation for both yields only in the case of the total amount of cane picked up before the "braceo."

In Figs. 2 and 3 are represented the values of the six quality variables for each of the replication, before and after the "braceo".

These values indicate that:

TABLE 4. Weights per linear meter (kg/m) of crushed and uncrushed canes collected before and after the "braceo"

Replication	On the furrow		At the head of the plot	
	Crushed	not crushed	Crushed	not crushed
		Before the "braceo"		
1	0.649	0.807	0.800	0.872
2	0.720	0.755	0.737	0.859
3	0.483	0.902	0.664	0.878
4	0.689	0.771	0.903	0.814
5	0.597	0.655	0.608	0.631
6	0.460	0.539	0.539	0.613
7	0.978	0.638	1.084	1.095
8	0.444	0.602	0.541	0.647
9	0.638	0.658	0.625	0.805
10	0.736	0.699	0.542	0.889
11	0.692	0.733	0.686	0.820
12	0.643	0.710	0.667	0.689
Average	0.644	0.706	0.700	0.801
Standard deviation	0.139	0.093	0.156	0.132
		After the "braceo"		
1	1.077	0.702	0.507	0.706
2	0.650	0.936	0.882	0.791
3	0.713	0.683	0.564	0.751
4	0.593	0.765	0.787	0.839
5	0.626	0.722	0.666	0.658
6	0.530	0.602	0.463	0.595
7	0.510	0.556	0.333	0.574
8	0.551	0.645	0.690	0.704
9	0.665	0.672	0.667	0.622
10	0.720	0.785	0.750	0.774
11	0.570	0.489	0.389	0.577
12	0.600	0.720	0.444	0.722
13	0.577	0.693	0.500	0.567
Average	0.645	0.690	0.588	0.683
Standard deviation	0.139	0.106	0.160	0.088

There is more fiber (Fig . 2A and 2B) in crushed canes than in complete canes. This is a logical result because crushing causes loss of juice but the amount of fiber remains the same. The difference is bigger in cane picked up after the "braceo" because in this case cane remains longer in the field resulting to greater losses of humidity.

The percentage of humidity (Fig . 2C and 2D) shows a situation which is contrary to what happened with fiber for in crushed cane there is an evident loss of cane juice (water).

The percentage of pol (Fig . 2E and 2F) and brix (Fig. 3A and 3B) in crushed cane is bigger than in complete cane in most cases. This apparent contradiction is due to the fact that the small quantities of soluble solids in the juice lost by the effects of crushing look larger when they are expressed in percentage for there is a great loss of water.

The percentage of reducing sugar (Fig . 3C and 3D) is higher in crushed cane than in uncrushed cane, owing to the fact that crushing accelerates deterioration of sugarcane quality.

Finally the percentage of purity (Fig . 3E and 3F) show that in general, quality of crushed cane is worse than quality of uncrushed cane.

It is important to say that in every variable the differences between crushed cane and uncrushed cane become bigger in cane picked up after the "braceo". This happens because in this case cane remains longer in the field.

On the average the weights per linear meter of crushed cane are less than the ones not crushed. (Table 4). This is due to the fact that crushing causes losses of cane juice. There are individual values showing a higher weight per linear meter of crushed cane because intensive crushing causes extraneous matter to stick to cane stalks, and this is difficult to separate.

CONCLUSIONS

Before the "braceo" operation in the field there is 3.825 t/ha of millable cane, 45% of which has been crushed by harvesting machinery. This amount represents 1.95% of the net yield. The losses of millable cane caused by mechanical harvesting with Push-Rake system, that is to say sugarcane that remains in the field after the "braceo", are about 2.760 t/ha, 45% has been crushed by the machinery. This amount on an average represents 1.47% of the net yield.

During the "braceo" operation an average of 1.065 t/ha of cane is collected, 47% of this cane has been crushed by the machinery. There is a directly proportional correlation of gross and net yield with amount of sugarcane existing in the fields before the "braceo" or last collection by hand. Quality variables show that

sugarcane was crushed by harvesting machinery, because cane mixed with extraneous matter, has less quality than the one that has not been crushed.

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PERDIDAS DE CAÑA EN CAMPOS COSECHADOS POR SISTEMA DE PEINE

M. C. Morales y V. Chaves Jr.

RESUMEN

Esta investigación se llevó a cabo en la Cooperativa de Agricultura Casa Grande, Valle Chicama, Costa Norte del Peru. El proposito fué determinar la cantidad de caña para molienda existente en el campo antes del "braceo" (ultima recolección manual), despues del "braceo" (perdidas) y la cantidad que es posible recolectar durante esta operación.

La recopilacion de informacion del campo consistio en recoleccion total repetidamente de caña existente en el campo, antes y después del "braceo", la operación se llevó a cabo en parecelas de 720 m^2 escogidas al azar. A la misma vez la porcion de tallos

triturados por equipo de cosecha fue separada de los no triturados y se llevo a cabo por separado un analisis de calidad de cada uno.

Los resultados mostraron que previo al "braceo" existe un promedio de 3.825 t/ha de caña para molienda o sea 1.95% del rendimiento neto. La perdida promedio de caña para molienda es de alrededor de 2.760 t/ha o 1.47% del rendimiento. La operacion del braceo es posible recoger en promedio 1.065 t/ha 45% de la caña recolectada (antes o despues del "braceo") es triturada por el equipo de cosecha. Existe una correlación proporcional directa de rendimientos bruto y neto con la cantidad de caña existente en el campo antes del "braceo". Las variables de calidad demuestran que la caña triturada por equipo de cosecha pierde en calidad en comparación con la caña no triturada.

MEASURING CUTTING RESISTANCE OF SUGAR CANE STALK WITH PENDULUMS

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ABSTRACT

Since power consumption of cutting sugar cane stalk is high, measuring cutting resistance is necessary for improving cutting efficiency. The pendulum is a simple device for measuring dynamic strength, but for a simple compact design with high capacity of energy storage and impact velocity requirement, a pair of pendulums with one torsional spring was used. The preliminary investigation revealed that the cutting resistance was greatly affected by the cutter geometries, particularly the sharpness of cutter edge. The difference of cutting resistance between a sharpened hand cutter and the less sharpened commercial base cutter of mechanical harvester was three to six times, the power loss for which cannot be overlooked.

INTRODUCTION

The objective of this study is to develop a simple device (the pendulum) to examine the cutting resistance of commercial cutters with different varieties of cane stalks. Cutting cane stalk is a high-power consuming work. A chopped sugar cane harvester is required to chop the cane stalk into pieces (Spargo and Baxter[6]). As such, measuring cutting resistance is necessary for improving the cutter design. Cutting is a dynamic action, the resistance of which is affected by the strength and hardness of cane stalk (Cochran and Baker[3]) and the geometry of the cutter and velocity of cutting (Chang[3], Mohsenin[4]), hence, cutting resistance should be considered as a composite property. Chang[2] have tried an impact cutting device to measure the cutting resistance. However, it involved a complicated instrumentation which was inconvenient.

The pendulum is a simple device for measuring dynamic strength of biological

materials (Buramistrova[5]) but its velocity can be limited by the design of arm length. For a base cutter, the common design of cutting velocity is about 10 m/sec. This paper suggests to use a pair of pendulums as shown in Fig. 1, one which is loaded with a torsional spring and tested cutter called actional pendulum, from which the energy input to the cutting system and the cutting velocity to be used are pre-determined. The surplus energy right after cutting through the material is measured by a second pendulum called reactional pendulum through an impact action. The actional pendulum is then stopped by a rubber stopper right after taking the impact action with the reactional pendulum at zero position. The advantage of using the torsional spring is that the energy storage capacity and the acting velocity can be increased several times without increasing the physical size of the pendulum.

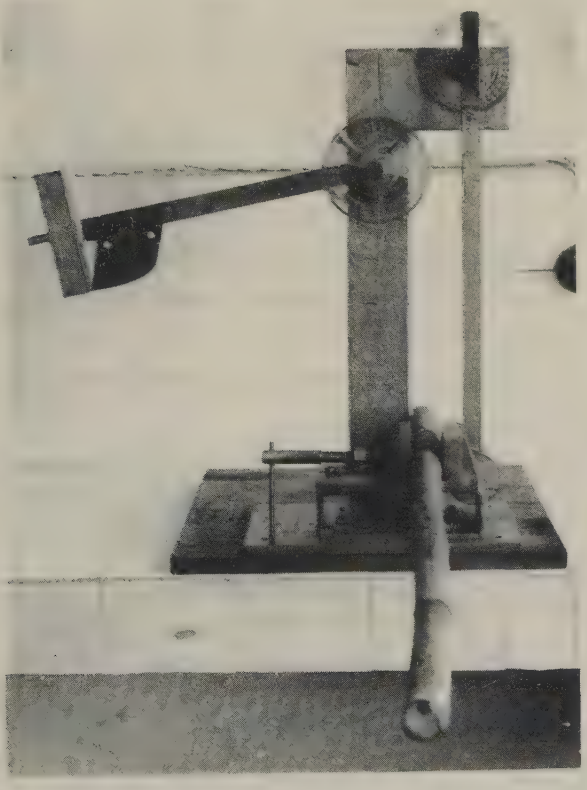


FIGURE 1. The device used for measuring cutting resistance. The actional pendulum with torsional spring on the rotating axle and a stopper with rubber at the center on the bottom of the hammer weight.

EXPERIMENTAL PROCEDURES

Theory and equations

The cutting energy absorbed by the cane stalk is determined as follows:

$$Ec = E_a - E_r \quad (1)$$

where

E_c = Energy absorbed by cane stalk through cutting in kgf-cm

E_a = energy delivered by the actional pendulum which is calculable, in kgf-cm

E_r = surplus energy after cutting and received by the reactional pendulum, in kgf-cm

The total energy E_a delivered by the actional pendulum is determined by the formula:

$$E_a = W.r\ (1 - \cos \theta_a) + \int_{\theta_i}^{\theta_i + \theta_a} K\theta\, d\theta \quad (2)$$

where

W = total weight of the actional pendulum including cutter weight in kgf

r = distance of the center of gravity of the actional pendulum with cutter measured from the rotating center in cm.

a = angle made by the actional pendulum from center position for the test in degree

i = initial angle of the torsional spring made by initial load in degree

= angle of torsional spring made by load in degree

K = spring constant of the torsional spring in kgf-cm/rad

Rad = angle of radians

The cutting velocity is then determined as follows:

$$V = \sqrt{\frac{2E_a}{M}} \quad (3)$$

where

V = cutting velocity in m/sec.

M = total mass of the actional pedulum in kg.

The average cutting force is determined by the formula:

$$F = \frac{E_c}{D} \tag{4}$$

where

F = average cutting force in kgf

D = diameter of cane stalk, or distance of cutting through the cane stalk, tangential direction.

The unit cutting resistance is then determined as follows:

$$R = \frac{F}{A}$$

$$\frac{E_c}{AD} \tag{5}$$

where:

R = cutting resistance in kgf/mc^2

A = cross - sectional area of cane stalk in cm^2

Construction

The actional pendulum has an arm made of 362 x 25.4 x 6.2 mm of steel plate and hammer made of 150 x 32 x 32 square bar; with a total weight of 1670 g. The reactional pendulum with an arm of 500 x 25.4 x 6.2 mm steel plate and a hammer of 64.5 dia 43 mm of circular plate; total working weight of which is 1110 g. The torsional spring is made of 4 mm steel wire with a coil diameter of 28 mm, spring constant of which is 26.9 kgf-cm/rd. A stopper is constructed at the center under the hammer of the actional pendulum with rubber. Two hammers are under contact at their vertical position at zero degree.

Calibration

The calibrations were done from 10° to 80° of the actional pendulum with four different spring conditions. The angle of the actional pendulum versus the corresponding angle of the reactional pendulum of the four spring conditions are shown in Fig. 2. The results showed that the angles between the actional and reactional pendulum are linear. The energy received by the reactional pendulum versus the corresponding reactional angle is shown in Fig. 3. This indicates that the energy – angle relationship is non-linear due to trigonometric function involved.

The energy received by the reactional pendulum is based on the energy delivered by the actional pendulum, therefore, the calibration included the impact loss.

Test

Three different commercial new cutters with three different varieties of cane

TABLE 1. Geometrical and mechanical conditions of the tested cutter blades

Cutter (Base cutter)	Edge Angle degree	Edge Sharpness mm	Blade thickness mm	Hardness Rookwell C
Hand cutter	15.6°	0.12	1.2	48-54
Santal (new)	32°	1.0 flate	3.8	38-46
Toft (new)	12.4°	0.53	4.6	42-51

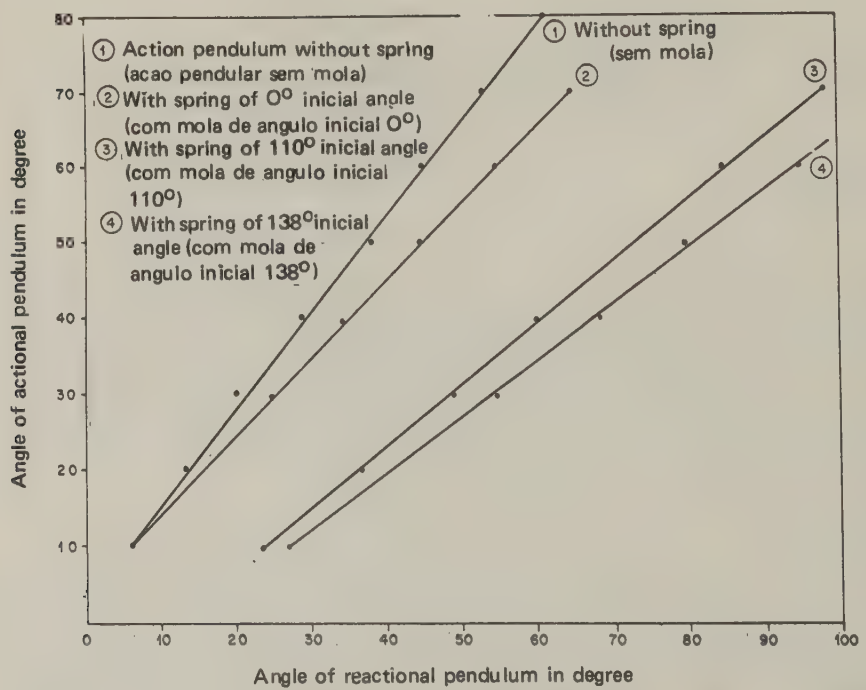

① Action pendulum without spring (acao pendular sem mola)
② With spring of O° inicial angle (com mola de angulo inicial O°)
③ With spring of 110° inicial angle (com mola de angulo inicial 110°)
④ With spring of 138° inicial angle (com mola de angulo inicial 138°)
① Without spring (sem mola)
Angle of actional pendulum in degree
Angle of reactional pendulum in degree
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2. Actional angle of the actional pendulum versus the corresponding reactional pendulum through an impact with four different conditions

TABLE 2. Cutting resistance of first internode with different cutters (preliminary results)

Sample		Cutting Resistance in kgf/cm^2		
		Hand cutter	Santal base cutter	Toft base cutter
CB-41-14	1		35.9	13
	2		17.6	20.5
	3	5.0	–	20.7
	4		33.1	17.7
	Ave.		28.8	17.7
NA56-79	1		21.9	15.4
	2	5.6	21.1	16.1
	3		19.7	16.4
	Ave.		20.9	15.8

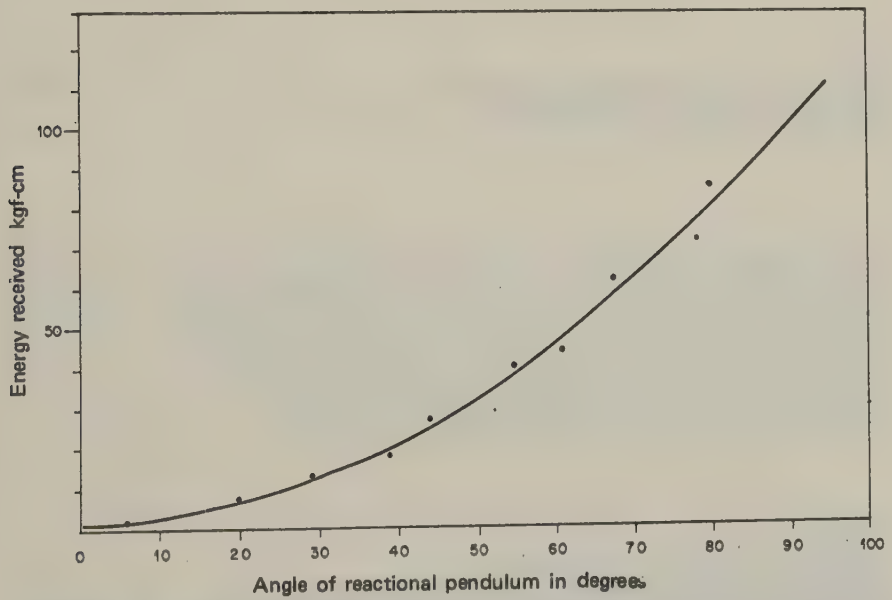
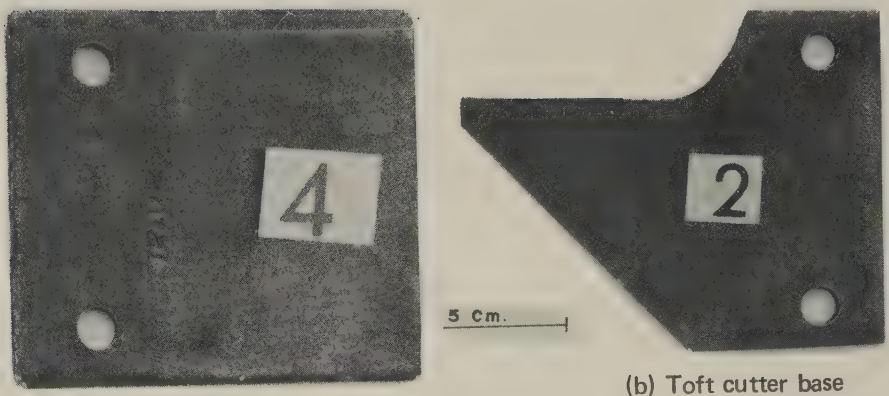


FIGURE 3. Energy received by the reactional pendulum (including energy loss of impact) versus the reactional angle.

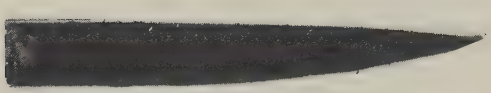
stalk were tested. The geometrical and mechanical conditions of the tested cutters are shown in Table 1 and Fig. 4 and 5. Two groups of tests were conducted. The first group was tested by a local hand cutter to cut piece of stalk from the first internode to the top at each middle part of internode with a cutting velocity of



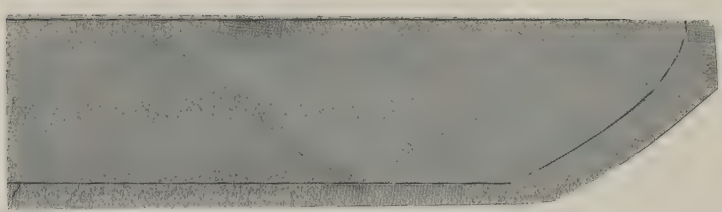
(a) Santal

(b) Toft cutter base

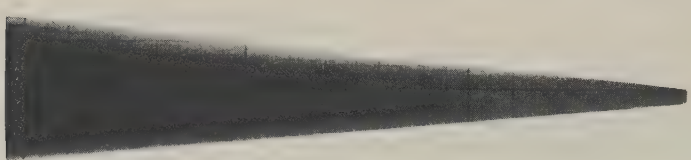
FIGURE 4. Sample cutters used for the tests (a) used by Santal (base cutter new); b) used by Toft (base cutter new)



(a) Hand cutter



(b) Santal base cutter



(c) Toft base cutter

FIGURE 5. Cross-sectional construction of the tested cutter, only projected on the edge. Actual size x 9.35

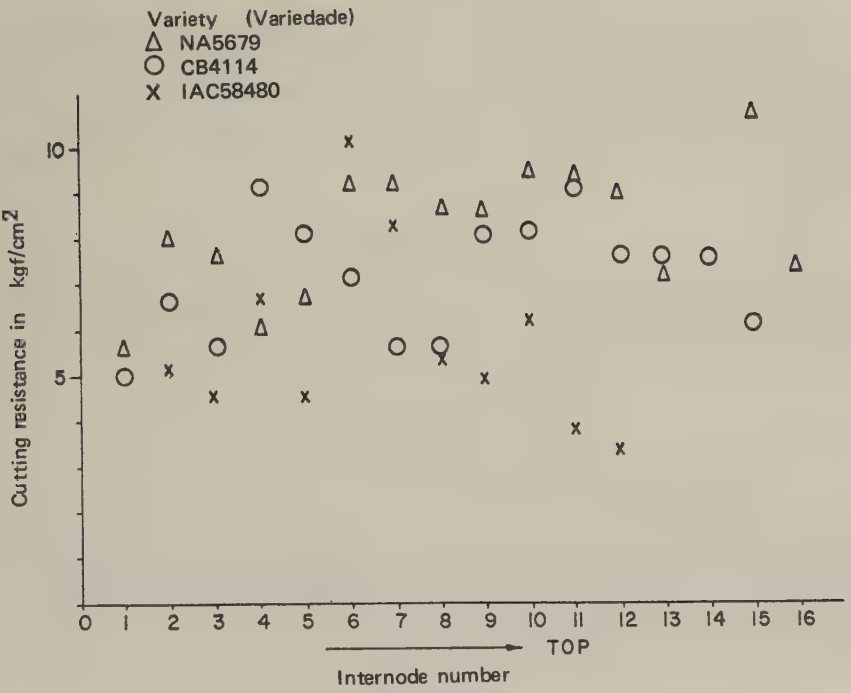


FIGURE 6. Distribution of cutting resistance with each number of internode reading taken at each middle part of internode with the hand cutter.

4.2 m/sec. Three different varieties were tested: NA56-79, CB41-14 and AIC58-480. The purpose of this test was to find out the distribution of the cutting resistance along a cane stalk. The second group of tests were conducted with three different commercial cutters: hand cutter, Santal and Toft. Only two of the varieties CB-41-14 and NA56-79 were tested with a cutting velocity of 4.1 to 4.3 m/sec. The purpose of this test was to make a preliminary investigation of the effect of different cutter geometries. Four samples of the first internode for each test were measured at the middle part, the results of which are shown in Table 2.

RESULTS AND DISCUSSION

The cutting resistance along the cane stalk from the bottom to the top cut by hand cutter with three different varieties as shown in Fig. 6 indicates that the cutting resistance distributed in the middle portion is harder than that distributed at the bottom and top internodes. Similar results were obtained by Martin and Cochran[4] for measuring hardness distribution. The results shown in Fig. 6 also indicate that the cane stalk respond to cutting resistance differently with different varieties. For using very sharp hand cutter with an edge sharpness of 0.12 mm,

the NA56-79 gave the highest cutting resistance. However, using unsharpened machine cutters of Santal and Toft as shown in Fig. 4, the results are different. The cutting resistance of CB41-14 is higher than that of NA56-79. This is possibly because the CB41-14 has a higher skin effect which is insensitive to sharp edge blade of hand cutter but very sensitive to the dull edge blade of machine cutters.

Fig. 4 also shows that the dull edge of machine cutters with a shapness of 0.53 mm of Toft to 1.0 mm of Santal had a cutting resistance three to six times more than that of cutting by the hand cutter which has a sharpness only of 0.12 mm, and blade thickness of 1.2 mm as shown in Fig. 5.

CONCLUSION

This preliminary investigation using the pair of pendulum revealed that the cutting resistance of sugar cane stalk was greatly affected by cutter geometries, especially the edge sharpness. It showed the possibility that the high power consumption of the present cane harvester can be reduced, if proper geometries of cutter can be used for the cane harvester.

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MEDIDAS CON PENDULO DE RESISTENCIA EN CORTE DE TALLOS DE CAÑA DE AZUCAR

Cheu-Sang Chang

RESUMEN

El consumo de fuerza al cortar tallos de caña de azucar es alto, haciendo necesario medir la resistencia de corte para mejorar la efeciencia de corte. El pendulo es el artefacto mas sencillo para medir fuerza dinamica, pero para un diseño simple y compacto con capacidad alta de almacenaniento de energia e impacto de velocidad necesario, se usa un par de pendulos con un muelle de torsion. La investigacion preliminar reveló que la resistencia de corte es afectada grandemente por la configuracion de la cuchilla de corte, en particular la agudeza del filo de la cuchilla. La diferencia de resistencia de corte entre una cuchilla afilada de corte manual y la cuchilla de base comercial menos aguda de una cosechadora mecanica es de tres a seis veces mas - una perdida de fuerza que no se puede pasar por alto.

SIMULATION MODELING OF POTENTIAL EVAPOTRANSPIRATION FOR IRRIGATED SUGARCANE

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ABSTRACT

A computer simulation model was developed for daily mean potential evapo-transpiration (PET) on weekly basis. The daily potential evapotranspiration data was estimated using the modified Penman equation, from 56–year historical hydrometeorological data collected. The model was developed, primarily, based on the assumption that little variation occurs during a week During the course of the model development, it was found that the occurrence of an isolated rainy days or a sequence of rainy days during a week is important, though the amount of rainfall has no significant effect on PET.

The PET was found to be a random variable for any week of the year, normally distributed, and the weekly means of these distributions had a deterministic relationship with the respective weeks of the year. The model makes use of these properties of PET in generating the data for any number of years. It is flexible enough to encompass the seasonal variations that occur during a week due to rainfall. For studying a complete crop production system, this PET model can be used as component of an over all crop environmental model describing the inputs of rainfall, evapo-transpiration and soil moisture variations with depth, as a basis for irrigation water allocation to intensive sugarcane production.

INTRODUCTION

Water resource development projects, especially in developing countries are becoming more and more vital because of high population density, increasing demands of food and fiber that should be fulfilled from within the country. Be-

cause of limited capital and other resources, it has been of great interest in both planning studies and other practical management problems, to increase the productivity of the farm land. In many of these countries in Asia, like Pakistan, it is found to be feasible by intensive irrigated cropping.

The introduction of intensive irrigated cropping essentially involves an extensive water control system that emphasizes efficient use of available supplies of irrigation water. This is more important in areas like Faisalabad in Pakistan where the trend for increasing amounts of water use for domestic, industrial and recreational purposes exists. Moreover, the importance of appropriate use of water is easily realized in such agricultural areas where water losses are significant and farmers usually over-irrigate. Many studies regarding the crop response to alternate soil moisture stresses reveal that such a phenomenon has an adverse effect on the over all crop yields.

For optimizing water allocation there is a need for exploring simple, quick and accurate methods for estimating the total consumptive use of water for various crops. Evapotranspiration, assumed to be equivalent to the consumptive use of the crop, is the most significant irrigation component among the decision variables for such management policy determinations. As a major soil moisture controlling factor it also has a significant effect on the crop yield.

Nature and Objective of the Study

The problem of obtaining a good estimate of actual evapotranspiration (ET) from an area is a difficult and complex task, but has been simplified by assumptions and representative point estimates. Many observers have tried to measure ET directly by some instruments and/or to estimate by developing relationships among the evapotranspiration and various climatological factors. The quality of the estimates depends upon the accuracy of the intruments and the mathematical models developed for this purpose. Further, the application and usage of these relationships are limited to the localities for which they were initially developed.

Experience has shown that due to the availability of computer facilities, the real world systems especially the probabilistic ones, where one or more controllable or uncontrollable variables are involved, have been very effectively represented and studied by Simulation Models. These have provided the opportunity to see and predict the effect of any change in a component of the system quickly without actually altering it. Keeping in view the practical usefulness of the simulation, it has been employed in estimating the evapotranspiration and resulting soil moisture inventories further, may be used in scientific irrigation scheduling, for new project feasibility investigations in determining the present inadequacies in the existing irrigation system as causes for low cropping intensities and yields, for determining the water requirements for adopting intensive cropping patterns, and in determining the quality and quantity of the sugarcane crop at the time of harvest.

The objective of the study was the development of a simulation model for evapotranspiration of the Faisalabad sugarcane growing district for weekly intervals. The model for atmospheric demand along with other input information like rainfall, irrigation water applied and ground water recharge or contribution to the root zone can be used in irrigation scheduling, production scheduling and the study of other problems like water logging and salinity through interpretation of the over-all water balance.

The Study Area

The aforementioned Simulation Model has been developed with special reference to a sugarcane producing and agriculturally renowned district, Faisalabad, which lies in the province of Punjab in Pakistan. In development of these models, the climatological data of Faisalabad has been used.

The province of Punjab consists of Lahore, Multan, Bahawalpur, Rawalpindi and Sargodha divisions. Faisalabad is one of the districts of Sargodha division. The whole area is part of a plain, with 0.25 m and 0.50 m per 10000 m. slope.

Punjab (the land of five rivers) is composed of a great mass of alluvium brought by the Indus and the five rivers Jehlem, Chenab, Ravi, Bias and Sutlej from Himalayas. The soils, of the most part, are sandy loam with localized textures of clay to silt. Limestone concretions and expanses of alkaline efflorescence are also found. The annual precipitation is too small for leaching to occur and most virgin lands respond generously to irrigation.

The temperature has extremes for the plains. The mean of minima for Lahore in January is only 45°C and the corresponding figure for maxima in June is 46°C. Frosts are frequent in January. Dust storms are a prominent feature of hot weather and are accompanied by a sudden drop in temperature and rise in relative humidity. Most of the rains occur in July and August. The submountain strip usually receives more precipitation as compared to plain areas. The mean annual precipitation for the mountains is 90 cm while it ranges to 5.0 cm for Multan 350 kilometers from the hills.

Agriculture is the main-stay of the Punjab, which is divided into three main areas, the submountain strip, the canal irrigated area and the arid margins. The canal area lies between the other two and includes the main mass of the modern irrigation system lying between the Jehlem and the Sutlej rivers. The rainfall varies from 50-60 cm along the northern margin and reduces very rapidly, in both amount and reliability, to the southwest and rainfed cropping decreases very markedly in this direction. The main crops are wheat, maize, sugarcane, rice and fodder.

Previous Studies on Crop Water Requirements

The studies of irrigation water requirements may be traced back many cen-

turies since irrigation was practiced in areas where the civilization first begun to rely on agriculture as a way of life. Early studies in USA were initiated during 1980's when the agricultural experimental stations were established. Mead[27] and Buffum[9] measured the amount of water applied to alfalfa, corn, wheat, barley and many other crops. Since then many scientists and engineers conducted many studies and developed various relationships regarding the water requirements and yield for different crops. Briggs and Shantz[6] were the first to recognize that the meteorological factors and solar energy are the basic causes of evapotranspiration which is the primary component in the water requirement estimates.

Relation of Evaporation and Evapotranspiration

Evaporation integrates many climatological factors which affect the plant consumptive use. Many research workers have treid to correlate evaporation and evapotranspiration. Pruitt and Angus[32] experimented on ryegrass and found that the evapotranspiration has direct relation with the class A pan evaporation. They found a pan coefficient varying from 0.7 to 0.8 Patil[20], Denmead and Shaw[12], Kigne[26] and Hensen[19] concluded that ratio of consumptive use to evaporation depends on the stage of the growth of crop. Rohwer[36] and many others related the pan A evaporation with lake or free water surface evaporation.

Formulas for Evaporation and Evapotranspiration

The actual measurement of evapotranspiration is difficult and complex. A number of theoretical and empirical formulas have been developed to relate evaporation from a free water surface to potential evapotranspiration on seasonal, monthly and daily basis. The actual evapotranspiration is then related to potential evapotranspiration by crop coefficient and soil moisture availability factors, a variable depending upon soil properties, soil moisture status, crop growth stage and rooting depth.

Among the estimation formulas, those of Thornthwaite[39], Blaney and Cirddle[5] and Penman[31] better known are. Many have developed empirical formulas based on observations and past data, whereas, Penman combined both the energy balance and aero-dynamic theory to derive a relationship between evapotranspiration and meteorological variables with a definite theoretical basis.

The Penman Equation

Since energy is required to sustain the evaporation process and a mechanism is needed to remove the water vapor, Penman presented a combination equation for evaporation from free water surface considering both the processes. The equation in its original form is given below:

$$E_o = \frac{\Delta}{\Delta + Y} (R_n + G) + \frac{Y}{Y + Y} EA \qquad (1)$$

where:

E_o = evaporation from free water surface, mm/day

Δ = slope of saturation vapor pressure curve at mean air temperature, de/dT

Y = psychrometric constant equal to 0.27

R_n = net radiation, mm/day
(note: 1 mm/day 59 cal/cm^2/day)

= $R_c - R_b$

R_c = incoming solar radiation, mm/day

r = albedo of the surface

n = actual bright sunshine hours per day

N = theoretical sunshine hours per day

a, b = constants: a = 0.18, b = 0.55

R_b = back (reflected) radiation, mm/day

= $T_a^4 (0.56 - 0.09/e_d) (0.1 + 0.9\ n/N)$

T_a^4 = black body radiation at mean air temperature (in K), mm/day

EA = vapor flow parameter, mm/day

$0.35 (e_a - e_d) (1 + 0.0098W_2)$

e_a = saturation vapor pressure at mean air temperature in mm. Hg

e_d = saturation vapor pressure at dew point

e_ax (relative humidity) in mm. Hg.

W_2 = mean wind speed at 2 meters above the ground surface, miles/day

G = heat flux from or to the soil for which a simple empirical relation is given by: (average daily air temp minus average

air temp. for previous three days) x 5 in which case the difference in daily mean temperatures is not significant, this heat flux can be ignored.

Simulation

Traditionally, policy making is based on the trial and error method and an improved quality is achieved as experience is accumulated with the passage of time. However, it is possible to reach an optimal design policy, especially when the system is too complex to handle, if an exact or appropriate relationship can be specified between the objective function and control variables. Alternate solutions are obtained by using the suitable values of control variables and the most favorable response of the system to any one or a combination of these changing parameters. This technique is called simulation and has been applied to a wide variety of real world systems or problems including the control systems, assignment of national policy alternatives, development of financial plans, agricultural planning and management, water resources development projects and many other natural but probabilistic and stochastic systems.

In water resources development and the crop environment in agriculture, many research workers and planners have introduced this technique in developing evapotranspiration and soil moisture status models to determine the overall irrigation requirements. They have made attempts to correlate these as inputs to the crop yield. The evapotranspiration and hence soil moisture content are essentially, functions of the irrigation and hydrologic cycle components.

A stream-flow Synthesis and Reservoir Regulation (SSARR) model was first developed by U.S. Army Corps Engineers in 1958 to count for rainfall, evapotranspiration and stream flow. Although this model had little direct concern with agriculture, it opened the door for the application of this approach to water management and control on agricultural lands. Later Crawford and Linsley[10] developed the Stanford Watershed model, a conceptual representation of the complete land phase of the hydrologic cycle.

The U.S. Department of Agriculture Hydrograph Laboratory (USDAHL) model development series started in the later 1960's. It was primarily developed to facilitate the understanding of interaction between the agricultural activities and hydrology under the direction of Holtan[20]. The publication of the first version of this model called the USDAHL–70 took place in 1970. This model had a specific purpose for agricultural applications, it has the potential for utilization on other problems as discussed by Holtan.

Norero *et al*[29] studied the effect of irrigation frequency on average evapotranspiration for various crop-climate-soil systems based on the equation which expresses evapotranspiration as function of soil moisture and potential evaporative

demand of the atmosphere as

$$\frac{d}{dy}(ET) = K\left(\frac{ET}{y}\right)\left(1 - \frac{ET}{ET_x}\right) \quad (2)$$

where ET is the actual evapotranspiration in mm/day, y is the total soil moisture potential in mm, K is a constant and ET_x is the potential evapotranspiration in mm/day.

A digital simulation model of dynamic soil moisture status was developed by Jones and Verma[24] stating the soil moisture at any depth in the root zone. An impermeable layer below the root zone was assumed. They presented the model in its functional form as follows:

$$M(y) = f(R, E, M_1(y), a, ET) \quad (3)$$

where M(y) is the moisture content at y inches of depth in cu. in/cu. in, $M_1(y)$ is the initial moisture content at y inches of depth in cu. in/cu, in, E is the evaporation in in/day, ET is the actual evapotranspiration in in/day, R is the effective rainfall in in/day, and a is representative of the physical properties of the soil.

Anderson and Maass[1] developed a model for simulation of irrigation systems dealing with more comprehensive parameters, e.g. crop response to irrigation water, effect of limited irrigation water supply on crop yield and computing water requirements and yield losses due to missed irrigation. They computed irrigation water requirements using a relationship, developed by Jensen and Haise, which is given as

$$ET_p = (0.014T - 0.37)R_s \quad (4)$$

where ET_p is the potential evapotranspiration in mm/day. T is the daily mean air temperature in ^oF and R_s is the solar radiation expressed in equivalent depth of water in mm/day.

Monte Carlo Technique of Simulation

A method of simulation, called the Monte Carlo technique, was proposed to simulate the weather parameters to account for the random nature of the variables by Roccaferrera[35]. It is a technique which was a series of random numbers to create a statistical distribution function. This is useful in studying the stochastic models of physical and mathematical processes.

The method of simulation is based on the fact that the probability distribution function of a random variable is known. The cumulative probability func-

tion varying from 0.0 to 1.0 is established for the entire range of a random variable. A random number is chosen/generated which simulates the variable corresponding to its level of cumulative probability. In this type of simulation, a system can be simulated many times in succession while inputs vary according to certain ways and the results are analyzed to obtain the required performance rating.

MATERIALS AND METHODS

The daily potential evapotranspiration is a product of many hydro-meteorological events like relative humidity, wind run, temperature and solar energy available at the surface of the earth. Since the nature of all of these variables is random, the mean potential evapotranspiration on weekly basis (PET) was modeled for the design of an over-all sugarcane production system. The basic concepts and general procedure are described below.

The Time Series

The occurrence of any meteorological event or a product of such events is considered to be stochastic as it is subjected to follow a certain probability function. The random variable X (t), being a function of time, t constitutes a stochastic time series. A time series is classified as stationary or non-stationary.

A stationary or constant time series comprises, all $X_i(t)$ random variable where t is a specified constant time during certain time interval, e.g., any event occurring during first week of January each year or temperature reading at 12.00 every day. The random variable is called constant in time space. Statistical parameters may be distinct and unique.

If a random event is occurring at constant time intervals of Z time units i.e. $X_i(t + z)$; where $t = 0, 1, 2, 3, \ldots$ and $Z = \text{const.}$, it forms a non-stationary or moving time series of Zth order lag and if $Z = 1$ it is called lag one time series.

In case any $X_i(t)$ is repeated at a constant time interval k such that $0 \text{ t } k \text{ t } 2k \ldots (n\text{-}1)\ k \text{ t } nk$; where n is any positive integer, it is called a periodic (Fourier) series of period 2k. The statistical parameters of a moving time series may vary even within each period.

Determination of PET

The daily mean potential evapotranspiration on weekly basis (PET) data was estimated under the following assumptions:

1. The daily potential evapotranspiration is a product of stochastic processes based on meteorological parameters.

2. The Penman Equation is sufficient to estimate daily potential evapotranspiration.

3. The study area was assumed to be homogenous i.e., the physical properties of the process do not change over the area under consideration.

4. Since the variables used in the Penman equation significantly differ on dry days from those on wet (rainy) days during the same week, the PET model was further subdivided into four sub-models to make it flexible for simulation on a daily basis. Each sub-model corresponds to the following weekly sequences based on a dry or a wet day of week: DD—sequence, a dry day preceded by a dry day; DW—sequence; a wet day preceded by a dry day; WD—sequence, a dry day preceded by a wet day; and WW—sequence, a wet day preceded by a wet day.

5. For the PET model based on whole week, irrespective of a rainy day or a dry day, it is assumed that on an average little seasonal variation occurs; whereas for sub-models it is assumed that a wet day has an effect on the following dry day or wet day.

A conceptual flow chart for computations of daily potential evapotranspiration and the PET sequences is given in Fig. 1.

PET Model Development

The following defines the weeks, the simulation year, a dry day, the meteorological data available and the method of PET determination. Normally a week is defined as composed of seven days but to count for 365th or 366th day of a normal year or a leap year respectively, the last week of a year was only of one or two days. In this way each year has 53 weeks. The simulation year corresponds to the cropping year of the study area. The first week of the year was the first week of October, starting the rabi or cool season and the season of sugarcane harvest. To account for the effect of a rainy day for submodels, a dry day was defined having rainfall less than 0.25 mm for that day; otherwise it was defined as a wet day. The meteorological data of one station in the study area was available on TAPE starting from July 1914 to December 1974. Due to some partially missing years of data, a total of 56 years of data were available for simulation purpose. The PET data based on whole week sequences (WK-sequences) and for weekly wet or dry sequences (DD, DW, WD and WW) were derived from the meteorological data using the modified Penman equation. The PET data value of every sequence corresponds to a week of the meteorological data.

Steps in Model Development

Since the first assumption postulates that PET is a stochastic random variable, it can be simulated by considering it in both stationary and non-stationary tune

spaces using the Monte Carlo technique. The sequential steps follow:

1. In stationary time space, taking each week of the PET Sequences as separate population, the statistical parameters like mean (X) variance (S^2) and coefficient of skewness (C_s) were estimated from sample size of maximum 56 observations – equal to the number of years of data as follow:

$$X(t) = \frac{\sum_{i=1}^{N} X_i(t)}{N}$$

$$s^2(t) = \frac{\sum_{i=1}^{N} X_i^2(t) - [\sum_{i=1}^{N} X_i(t)^2 / N}{(N-1)}$$

$$C_s = \frac{N}{(N-1)(N-2)} \sum_{i=1}^{N} [X_i(t)]^3 / s^3$$

where

$X(t), s^2(t)$ = are unbiased estimates of population mean and variance, respectively for the week.

$C_s(t)$ = coefficient of skewness for the week.

i, t = indices for year and week, respectively.

N = number of none zero values of PET in stationary time space.

Further statistical analysis of PET sequences suggested that each $X_i(t)$ in stationary time space is approximately normally distributed.

2. The behaviour of PET (population mean for each week) in non-stationary time space was found to be deterministic and highly correlated with corresponding week of year showing that it is periodic as well. Fig. 2 shows the behaviour of PET in both stationary and non-stationary time spaces.

3. Uniform random numbers ranging from 0.0 to 1.0 were generated to simulate any of the PET sequences using the Monte Carlo Technique.

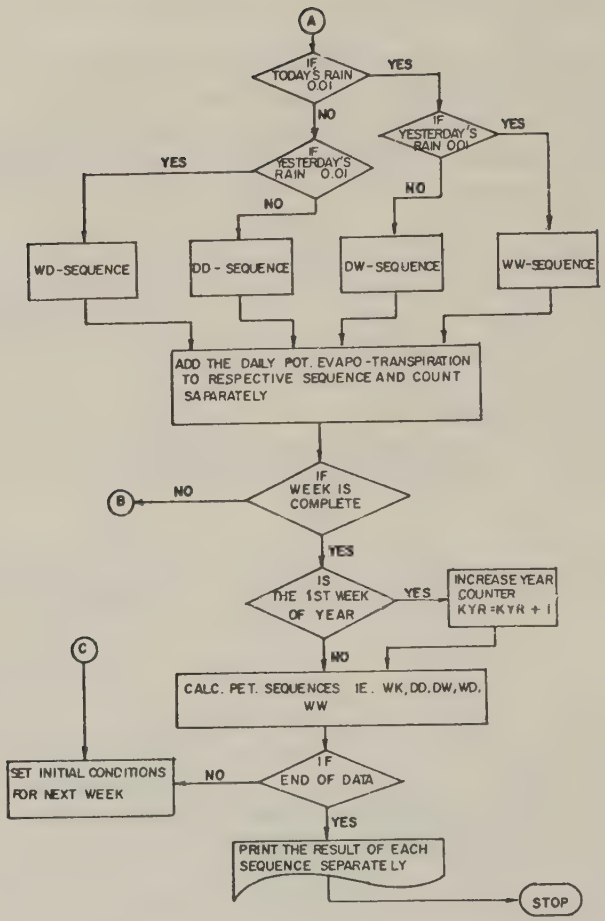

FIGURE 1. Flow chart for calculating daily potent evapotranspiration and PET. Sequences from meteorological data using Penman equation (modified)

RESULTS AND DISCUSSION

The PET Data

The PET for all sequences (WK, DD, DW, WD and WW) was computed from the daily potential evapotranspiration values as estimated from 56 years of meteorological data using the modified Penman equation. For this year the minimum evaporative demand of the atmosphere for WK-sequence is 0.69 n.m/day during 34th week while its maximum value during 39th week is 5.83 mm/day.

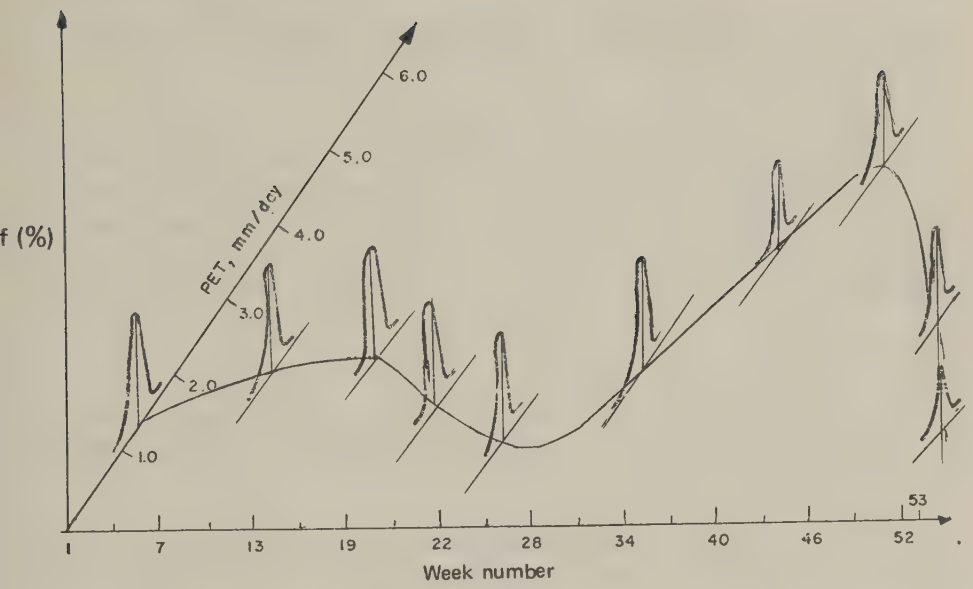

FIGURE 2. Weekly means of WK-sequence of PET, and frequency curves in constant time space a schematic representation.

Tests for hypothesis of equal means of week of any sequence and corresponding weeks of other sequences

For statistical analysis each week of a sequence was considered as an independent population. To test the hypothesis that the potential evapotranspiration on a dry day varies significantly from that on a wet day during a week, the null hypothesis of equal means of all sequences for each week was tested by applying two tests as proposed by Dixon and Massy 14, the t-test for equal number of observations.

Before conducting formal tests, the basic criteria whether the populations under test have equal variances and are normally distributed was verified by computing the F-statistics (Table 1), coefficient of Skewness and frequency analysis for WK-sequence (Fig. 3).

The t-statistics for six possible combination of sequences DD, DW, WD and WW (DD-DW, DD-WD, DD-WW, DW-WD, DW-WW, and WD-WW) were computed. It was concluded, at 95% level of probability, that for most of the weeks especially in summer (hot season) these sequences differ from each other (Table 2).

The confidence limits for each contrast of the sequences DD, DW, DD and WW with WK-sequences were computed for different levels of significance. Table 3 presents the results of contrasts and their confidence limits at 5% level of significance. It can be stated that, at 95% level of probability, most of the weeks of all

sequences except WK and DD differ from each other especially in the hot season. This also confirms the conclusion drawn in the first test.

A pictorial comparison of the PET sequences is depicted in Fig. 4 as well. From this figure, it can be seen that the weekly means of WK and DD sequences are almost the same but the sequences DD, DW, WD and WW differ from each other in order from maximum to minimum. Further, the difference for these sequences from week No. 1 to week No. 29 are not significant but after this they start increasing and about 37th week (middle of June) the differences become maximum.

The Computer Program

A computer program, embodying the variables and relationships used in the Penman equation, was written in Fortran—IV language. It consists of a MAIN and following sub-routines:

1. MEANS 2: Calculates the monthly means for the basic meteorological data variables to fill the missing data for the corresponding months.

2. EVAPO: Calculates the daily potential evapotranspiration using the modified Penman equation and calling mother sub-routine SOLAR 2 where solar radiation, theoretical sunshine hours and the aero-dynamic part of the Penman equation are calculated.

3. CORECT: Replaces the very low and very high values of PET data due to some erroneous basic data by the mean value for that week calculated by another subroutine, called here, MEAN.

4. OUTP: The subroutine OUTP prints the PET sequences separately.

5. TEST 2: Performs various statistical tests by computing various parameters like means, variances and coefficient of skewness and calling sub-routines FSTAT, TEST 1 and FRQ. FSTAT computes the F-statistic for testing the null hypothesis of equal variances; whereas TEST 1 performs the t-test for testing the null hypothesis of equal means and also finds the frequencies for WK-sequence calling the subroutine FREQ.

6. YRMEAN: Calculates the yearly means of PET to see the seasonal trend year after year.

7. PETRAN: It computes the PET only for rainy days and the corresponding average amount of rainfall to see the dependence of PET on the amount of rainfall.

TABLE 1. F-Statistics for Testing the Hypothesis of Equal Variances for Each Week of PET Sequences

	Sequences Under Consideration $V_1 = 55$											
	WK–DD			WK–DD			WK–DD			WK–DD		
Week	F	v_2	f_{v_1,v_2}	F	v_2	f_{v_1,v_2}	F	v_2	f_{v_1,v_2}	F	v_2	f_{v_1,v_2}
1	1.084	55	1.56	0.347	4	5.69	1.421	6	3.75	0.241	2	19.5
2	1.016	55	1.56	0.486	3	8.58	0.825	4	5.69	–	–	–
3	0.967	55	1.56	1.140	5	4.44	2.331	5	4.44	–	–	–
4	1.021	55	1.56	0.350	4	5.69	0.364	2	19.50	–	–	–
5	0.995	55	1.56	2.856	5	4.44	1.535	5	4.44	3.166	–	252
6	1.015	55	1.56	0.327	2	19.50	0.548	2	19.50	–	–	–
7	1.000	55	1.56	1.580	3	8.58	0.975	2	19.50	–	–	–
8	0.979	55	1.56	1.349	3	8.58	0.395	3	8.58	–	–	–
9	1.035	55	1.56	0.233	3	8.58	1.956	3	8.58	–	–	–
10	0.968	55	1.56	0.758	10	2.63	0.637	6	375	2.109	2	19.50
11	1.057	55	1.56	0.383	9	2.80	1.043	7	3.33	3.039	2	19.50
12	0.975	55	1.56	1.185	7	3.31	0.406	8	3.01	0.073	1	252
13	0.976	55	1.56	0.724	6	3.75	3.424	6	3.75	34.321	1	252
14	0.901	55	1.56	0.197	11	2.50	0.227	203	2.63	0.231	2	19.50
15	0.977	55	1.56	0.665	12	2.49	1.909	14	2.17	0.954	6	2.75
16	0.885	55	1.56	0.995	14	217	1.015	11	2.50	1.922	5	4.44
17	1.080	55	1.56	0.452	12	2.38	0.622	11	2.50	1.028	2	19.50
18	0.905	55	1.56	0.999	17	2.07	0.773	14	2.17	0.329	1	252
19	1.148	55	1.56	0.550	11	2.50	1.072	16	2.10	0.760	5	4.44
20	1.009	55	1.56	0.460	10	2.63	1.251	6	2.75	1.846	2	19.50
21	1.144	55	1.56	1.739	13	2.37	1.911	14	2.17	3.368	2	19.50
22	1.024	55	1.56	0.813	12	2.38	1.203	10	2.63	7.254	4	5.69
23	0.969	55	1.56	0.589	17	2.07	1.479	17	2.07	1.187	6	3.75
24	1.086	55	1.56	0.550	11	2.50	1.852	12	2.38	59.915	4	5.69
25	0.992	55	1.56	0.881	17	2.07	3.416*	15	2.17	4.696	6	3.75
26	0.806	55	1.56	2.405*	17	2.07	2.583*	19	1.97	3.608	4	5.69
27	0.970	55	1.56	0.873	14	2.17	0.834	11	2.50	0.548	6	3.75
28	0.961	55	1.56	1.234	15	2.17	1.053	20	1.96	1.253	6	3.75
29	0.862	55	1.56	0.512	15	2.17	0.609	14	2.17	207	1	252
30	1.100	55	1.56	0.935	11	2.50	3.093*	9	2.80	360	1	252
31	1.002	55	1.56	1.479	7	3.31	0.338	9	2.80	0.340	2	19.50
32	0.979	55	1.56	0.577	14	2.17	1.609	13	2.20	1.725	5	4.44
33	0.992	55	1.56	0.737	19	1.97	0.940	17	2.70	0.386	6	3.72
34	1.081	55	1.56	0.616	11	2.50	0.496	13	2.20	81.940	1	252
35	0.818	55	1.56	1.183	10	2.63	0.139	11	2.50	3.242	1	252
36	0.818	55	1.56	0.895	11	2.50	0.608	9	2.80	0.0	0	–
37	1.265	55	1.56	0.969	18	2.07	0.788	18	2.0	1.168	2	19.50
38	1.305	55	1.56	0.513	15	2.17	0.628	15	2.17	0.145	1	252
39	0.899	55	1.56	0.989	21	1.96	0.437	23	1.88	0.338	6	3.75
40	1.007	55	1.56	0.665	22	1.90	0.588	20	1.88	1.392	9	2.80
41	1.354	55	1.56	1.472	22	1.90	1.305	20	1.96	0.862	9	2.80
42	0.696	55	1.56	0.907	30	1.75	0.505	32	1.72	0.959	11	2.50
43	0.855	55	1.56	0.434	31	1.74	0.473	33	1.72	0.777	14	2.17
44	0.855	55	1.56	1.033	31	1.74	0.793	29	1.76	1.186	12	2.38
45	1.144	55	1.56	0.711	27	1.80	0.711	32	1.72	0.585	13	2.20
46	1.197	55	1.56	0.694	28	1.80	0.969	28	1.76	0.461	14	2.17
47	0.847	55	1.56	0.660	35	1.70	0.616	26	1.70	0.706	9	2.80
48	1.388	55	1.56	1.088	26	1.85	0.888	27	1.85	0.609	9	2.80
49	0.970	55	1.56	0.620	19	1.97	0.991	19	1.97	0.938	11	2.50
50	0.871	55	1.56	0.757	9	2.80	0.436	12	2.38	0.385	1	252
51	0.887	55	1.56	1.337	11	2.50	0.751	12	2.38	0.385	5	4.44
52	0.981	55	1.56	0.772	13	2.0	1.422	10	2.63	2.63	0	
53	1.096	55	1.56	1.650	1	262	2.253	3	5.58	5.58	0	–

**Variance not equal at = 0.05*

Note: At = 0.01 all sequences have equal variances for respective weeks.

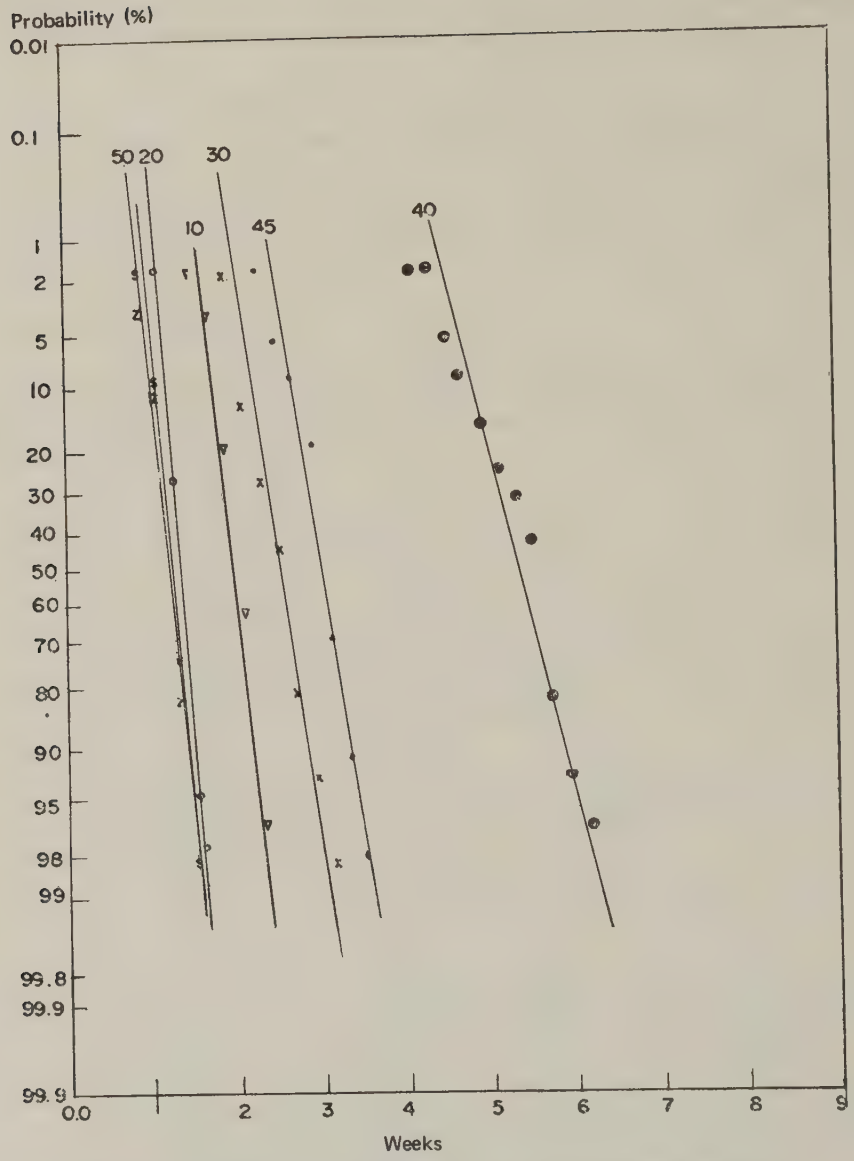

FIGURE 3. Cummulative frequency curves for some randomly selected weeks of WK sequence of PET

Regression analysis for weekly means and variances

Table 4 contains the weekly means and variances for each sequence. Stepwise regression analysis was carried out to fit the polynomial equations to these parameters. Since the PET sequences are bimodal, the two different fourth order

TABLE 2. T-Statistics for Testing the Hypothesis of Equal Means of PET. Sequences (Equal No. of Observations)

Week	Degree of Freedom (df)	t (df) 0.975	T-Statistics for Sequences under Consideration					
			DD-DW	DD-WD	DD-WW	DW-WD	DW-WW	WD-WW
1	2	4.303	0.416	−0.665	1.070	−1.042	0.828	1.396
5	2	4.303	0.386	1.418	2.108	6.587*	4.338*	1.999
10	4	2.571	0.592	0.714	0.982	0.078	0.045	0.481
14	4	2.571	−1.152	−0.500	−0.399	0.551	0.825	0.154
15	10	2.228	0.539	1.023	0.312	0.109	0.042	−0.090
16	8	2.306	1.555	3.851*	3.644*	1.515	1.694	0.537
17	4	2.571	0.600	0.584	1.423	−0.158	0.428	0.774
19	4	2.571	9.993	0.799	−0.342	−0.342	−1.788	−1.304
20	4	2.571	1.188	1.951	1.887	0.181	−0.034	−0.297
21	2	4.303	2.179	3.557	12.866*	0.291	0.773	0.607
22	4	2.571	2.076	2.263	2.446	−0.498	−0.390	0.183
23	4	2.571	0.796	4.153*	2.313	4.088*	2.088	−0.553
24	4	2.571	1.318	11.31*	22.490*	0.342	1.994	Large Value*
25	10	2.228	1.58	2.594*	4.464*	2.286*	3.452*	2.461*
26	6	2.447	2.433	2.382	5.228*	−1.685	42.038*	39.044*
27	10	2.228	0.127	1.288	1.009	1.173	0.911	0.106
28	10	2.228	1.277	2.379*	3.642*	1.093	2.495*	1.518
29	2	4.303	−0.734	−0.503	0.626	0.321	1.878	1.796
32	8	2.306	−1.459	0.210	0.456	1.509	1.901	0.192
33	12	2.179	1.716	1.430	3.182*	−0.187	−4.924*	−4.52*
35	2	4.303	1.192	Large Value*	2.678	Large Value*	0.532	23.449
37	2	4.303	0.296	1.229	1.517	0.790	1.170	0.568
39	6	2.447	1.814	0.696	2.710*	−0.183	2.005	1.434
40	16	2.12	3.165*	2.429*	3.885*	−0.451	0.797	1.148
41	16	2.12	3.6788	2.251*	3.299*	−0.743	0.195	0.831
42	16	2.12	1.846	2.181*	3.883*	0.650	2.48*	1.494
43	20	2.086	2.324*	1.791	3.193*	−0.650	0.688	1.449
44	18	2.101	0.468	−0.134	1.627	−0.743	1.145	2.619*
45	20	2.086	0.753	1.034	1.553	0.194	0.609	0.429
46	26	2.056	2.943*	3.745*	4.409*	0.248	1.374	1.266
47	14	2.145	1.674	1.311	3.022	−0.806	1.295	2.368*
48	12	2.179	1.951	2.291*	2.934	0.069	1.210	1.210
49	16	2.12	1.173	1.612	1.883	0.151	0.467	0.387
51	6	2.447	2.064	2.807*	1.864	0.086	−0.501	−0.937

**The means for these sequences of PET are different at 5% of level of significance.*

polynomial equations for each sequence gave the highest correlation with the week of the year. These equations, along with respective R^2 values, are presented in Table 5.

The R^2 values for all equations, except for the first equation of WW-sequence where it becomes to be 0.37, range from 0.97 to 0.99 which are quite satisfactory. The value of R^2 for the first equation of WW-sequence is low because most of the PET values during the period of week No. 1 to week 25 (i.e., winter season) are zero.

TABLE 3. Confidence Limits for Testing the Hypothesis of Equal Means of PET Sequences ($\alpha = 0.05$) (Un-equal No. of Observations)

	Sequence Under Consideration (Contrast)							
	WK-DD		WK-DW		WK-WD		WK-WW	
Week	Contrast-1	Conf. Limit	Contrast-2	Conf. Limit	Contrast-3	Conf. Limit	Contrast-4	Conf. Limit
1	−0.007	0.086	0.095	0.213	0.152	0.196	0.301	0.270*
2	−0.005	0.0	0.229	0.0	0.243	0.0	1.574	0.0
3	−0.005	0.0	0.068	0.0	0.177	0.0	1.579	0.0
4	−0.004	0.105	0.223	0.260	0.388	0.330*	−0.024	0.562
5	−0.006	0.076	0.032	0.172	0.192	0.172*	0.267	0.288
6	−0.002	0.092	0.172	0.290	0.115	0.290	0.247	0.293
7	−0.001	0.0	−0.038	0.0	0.090	0.0	2.089	0.0
8	0.002	0.092	0.063	0.0	0.430	0.0	2.134	0.0
9	−0.004	0.107	0.108	0.186	0.156	0.226	0.193	0.335
10	−0.004	0.107	0.108	0.186	0.156	0.226	0.193	0.335
11	−9.005	0.089	0.132	0.162	0.154	0.178	−0.001	0.280
12	−0.002	0.089	0.125	0.177	0.103	0.169	0.294	0.338
13	−0.00	0.094	0.156	0.200	0.064	0.200	0.067	0.359
14	−0.003	0.091	0.032	0.153	0.105	1.158	0.112	0.285
15	−0.014	0.121	0.172	0.197	0.142	0.186	0.204	0.256
16	−0.111	0.070	0.032	0.108	0.120	0.119*	0.179	0.160*
17	−0.006	0.091	0.055	0.149	0.046	0.154	0.250	0.287
18	−0.011	0.105	0.080	0.150	0.055	0.161	0.237	0.399
19	−0.024	0.089	0.010	0.149	0.122	0.130	0.039	0.202
20	−0.006	0.089	0.178	0.156	0.121	0.190	0.115	0.281
21	−0.007	0.092	0.236	0.145*	0.147	0.142*	0.326	0.288
22	−0.007	0.080	0.162	0.131	0.182	0.140*	0.183	0.199
23	−0.046	0.095	0.095	0.107	0.162	0.107*	0.211	0.158*
24	−0.013	0.048	0.062	0.081	0.129	0.078*	0.259	0.118*
25	−0.016	0.042	0.079	0.060*	0.123	0.062*	0.173	0.088*
26	−0.011	0.071	0.302	0.102*	0.310	0.098*	0.553	0.175*
27	−0.024	0.134	0.110	0.207	0.223	0.226	0.240	0.285
28	−0.019	0.161	0.165	0.241	0.233	0.217*	0.245	0.341*
29	−0.021	0.188	0.130	0.283	0.247	0.290	0.520	0.717
30	−0.035	0.215	0.394	0.361*	0.272	0.390	0.730	0.818
31	−0.015	0.263	0.096	0.525	0.543	0.477*	0.523	0.824
32	−0.001	0.207	−0.132	0.319	0.181	0.328	0.146	0.471
33	−0.030	0.275	0.254	0.379	0.378	0.394	−0.069	0.583*
34	−0.040	0.236	0.505	0.398*	0.503	0.374*	0.709	0.900
35	−0.016	0.230	0.327	0.402	−1.825	0.402	0.780	0.878
36	−0.047	0.275	0.475	0.463*	0.644	0.500*	1.432	1.470
37	−0.019	0.300	0.425	0.424*	0.470	0.421*	0.725	0.940
38	−0.032	0.277	0.405	0.415	0.302	0.415	1.067	1.054*
39	−0.082	0.309	0.189	0.411	0.399	0.399	0.974	0.655*
40	−0.096	0.211	0.425	0.277*	0.348	0.273*	0.630	0.383*
41	−0.090	0.193	0.444	0.252*	0.308	0.261*	0.648	0.350*
42	−0.107	0.199	0.214	0.235	0.218	0.231	0.566	0.334*
43	−0.088	0.192	0.266	0.288*	0.208	0.221	0.380	0.296*
44	−0.049	0.178	0.240	0.208*	0.232	0.213*	0.361	0.290*
45	−0.027	0.163	0.203	0.200*	0.121	0.190	0.204	0.258
46	−0.091	0.158	0.215	0.191*	0.154	0.191	0.400	0.243*
47	−0.059	0.159	0.145	0.180	−0.001	0.178	0.370	0.289*
48	−0.042	0.136	0.233	0.169*	0.169	0.167*	0.201	0.248
49	−0.010	0.080	0.144	0.145	0.196	0.130*	0.437	0.305*
50	−0.010	0.080	0.144	0.145	0.196	0.130*	0.437	0.205*
51	−0.12	0.065	0.182	0.109*	0.210	0.106*	0.159	0.148*
52	−0.020	0.076	0.158	0.120*	0.130	0.132	0.261	0.405
53	−0.064	0.106	0.275	0.404	0.332	0.291*	0.523	0.567

Sequences are different at 0.05

TABLE 4. Statistical Parameters of PET. Sequences for Each Week (From 56-yrs. of Data)

	Sequences									
	WK		DD		DW		WD		WW	
Week	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
1	1.35	0.019	1.35	0.017	1.25	0.055	1.31	0.013	1.09	0.079
2	1.57	0.031	1.58	0.031	1.35	0.065	1.33	0.038	0.0	0.0
3	1.76	0.026	1.76	0.027	1.69	0.023	1.58	0.011	0.0	0.0
4	1.91	0.029	1.92	0.029	1.69	0.083	1.53	0.083	1.94	0.0
5	1.98	0.017	1.99	0.017	1.95	0.006	1.79	0.011	1.71	0.005
6	2.05	0.023	2.05	0.023	1.88	0.071	1.93	0.043	1.80	0.0
7	2.09	0.025	2.09	0.025	2.13	0.016	1.99	0.025	0.0	0.0
8	2.09	0.023	2.09	0.024	1.95	0.017	2.01	0.059	1.94	0.0
9	2.13	0.026	2.14	0.025	2.07	0.113	1.79	0.013	0.0	0.0
10	2.29	0.031	2.29	0.032	2.18	0.041	2.13	0.048	2.09	0.015
11	2.25	0.021	2.25	0.020	2.12	0.055	2.09	0.020	2.25	0.007
12	2.21	0.019	2.21	0.019	2.08	0.016	2.10	0.046	1.91	0.259
13	2.17	0.026	2.17	0.026	2.01	0.035	2.10	0.007	2.10	0.001
14	1.93	0.014	1.94	0.015	1.90	0.071	1.83	0.062	1.82	0.060
15	1.90	0.041	1.92	0.042	1.73	0.062	1.76	0.022	1.70	0.043
16	1.80	0.014	1.81	0.015	1.77	0.014	1.68	0.014	1.62	0.007
17	1.73	0.021	1.73	0.020	1.67	0.047	1.68	0.034	1.48	0.021
18	1.61	0.029	1.63	0.032	1.53	0.029	1.56	0.037	1.38	0.088
19	1.49	0.022	1.52	0.019	1.48	0.040	1.37	0.021	1.45	0.029
20	1.40	0.021	1.41	0.021	1.23	0.046	1.28	0.017	1.29	0.012
21	1.24	0.028	1.25	0.025	1.00	0.016	1.09	0.015	0.91	0.021
22	1.13	0.019	1.14	0.019	0.97	0.023	0.95	0.016	0.95	0.003
23	0.99	0.015	1.04	0.016	0.90	0.026	0.83	0.010	0.78	0.013
24	0.73	0.007	0.74	0.006	0.67	0.012	0.060	0.004	0.47	0.0
25	0.60	0.005	0.61	0.005	0.52	0.006	0.47	0.002	0.42	0.001
26	1.07	0.015	1.08	0.019	0.76	0.006	0.76	0.006	0.51	0.004
27	1.57	0.048	1.60	0.049	1.46	0.055	1.35	0.057	1.33	0.087
28	2.09	0.075	2.11	0.078	1.93	0.061	1.86	0.071	1.75	0.060
29	2.58	0.083	2.60	0.096	2.45	0.162	2.33	0.136	2.06	0.0
30	3.14	0.144	3.17	0.131	2.75	0.154	2.87	0.047	2.41	0.0
31	3.73	0.171	3.75	0.171	3.63	0.116	3.19	0.507	3.21	0.505
32	4.05	0.119	4.05	0.122	4.19	0.206	3.87	0.074	3.91	0.069
33	4.41	0.193	4.44	0.195	4.16	0.262	4.03	0.205	5.48	0.500
34	4.74	0.144	4.78	0.133	4.23	0.233	4.23	0.29	2.03	0.002
35	5.06	0.106	5.08	0.100	4.74	0.90	6.89*	0.76	4.28	0.033
36	5.52	0.189	5.56	0.231	5.04	0.211	4.87	0.31	4.08	0.0
37	5.63	0.263	5.65	0.212	5.20	0.277	5.16	0.341	4.90	0.23
38	5.59	0.196	5.92	0.151	5.18	0.383	5.29	0.313	4.52	1.35
39	5.48	0.210	5.56	0.233	5.29	0.212	5.08	0.48	4.51	0.621
40	4.65	0.111	4.75	0.110	4.23	0.167	4.31	0.189	4.03	0.08
41	4.45	0.125	4.53	0.092	4.00	0.085	4.14	0.096	3.80	0.145
42	4.14	0.083	4.25	0.119	3.93	0.091	3.92	0.164	3.57	0.139
43	3.76	0.073	3.85	0.078	3.49	0.168	3.55	0.154	3.39	0.094
44	3.49	0.084	3.54	0.098	3.25	0.081	3.25	0.106	3.13	0.071
45	3.12	0.067	3.15	0.058	2.92	0.094	3.00	0.094	2.92	0.114
46	2.72	0.064	2.81	0.054	2.50	0.092	2.56	0.066	2.32	0.139
47	2.33	0.056	2.39	0.066	2.19	0.085	2.33	0.091	1.96	0.080
48	1.96	0.055	2.01	0.041	1.73	0.051	1.79	0.062	1.66	0.091
49	1.75	0.034	1.78	0.035	1.52	0.055	1.57	0.034	1.49	0.036
50	1.32	0.015	1.33	0.017	1.17	0.020	1.12	0.035	0.88	0.039
51	1.00	0.011	1.02	0.013	0.82	0.009	0.79	0.015	0.85	0.009
52	1.20	0.016	1.22	0.017	1.04	0.021	1.07	0.011	0.94	0.0
53	1.32	0.034	1.39	0.031	1.05	0.021	0.99	0.915	0.80	0.0

TABLE 5. Regression Coefficients for Weekly Mean and Variance Equations

Means	Week Sequence	a Intercept	b X	c X^2	d X^3	e X^4	r^2
Weekly–1	1–25	1.19	0.21	–0.01	–	0.000004	0.99
Weekly–2	26–53	0.06	0.71	–	–0.003	0.00007	0.98
Dry-Dry–1	1.–25	1.20	0.21	–0.01	–	0.000003	0.99
Dry-Dry–2	26–53	0.06	0.72	–	–0.003	0.00007	0.98
Dry-Wet–1	1.–25	1.02	0.23	–0.01	–	0.000004	0.98
Dry-Wet–2	26–53	–0.02	0.68	–	–0.003	0.00006	0.98
Wet-Dry–1	1–25	1.14	0.14	–	–0.0006	0.00001	0.98
Wet-Dry–2	26–53	0.23	0.72	–	–0.003	0.00007	0.92
Wet-Wet–1	1–25	0.32	0.72	–	–0.0005	0.000007	0.37
Wet-Wet–2	26–53	-0.08	0.64	–	–0.002	0.00006	0.97
Wet-Wet–2	26–53	–0.08	0.64	–	–0.002	0.00006	0.97
Variances							
Weekly	1–53	0.06	–0.010	0.0005	–	–0.0000001	0.62
Dry-Dry	1–53	0.06	–0.009	0.0005	–	–0.0000001	0.63
Dry-Wet	1–53	0.07	–0.006	–	0.00002	–0.0000003	0.51
Wet-Dry	1–53	0.10	–0.019	0.0010	–	–0.0000002	0.42
Wet-Wet	1–53	0.02	–0.008	–	0.00004	–0.0000005	0.19

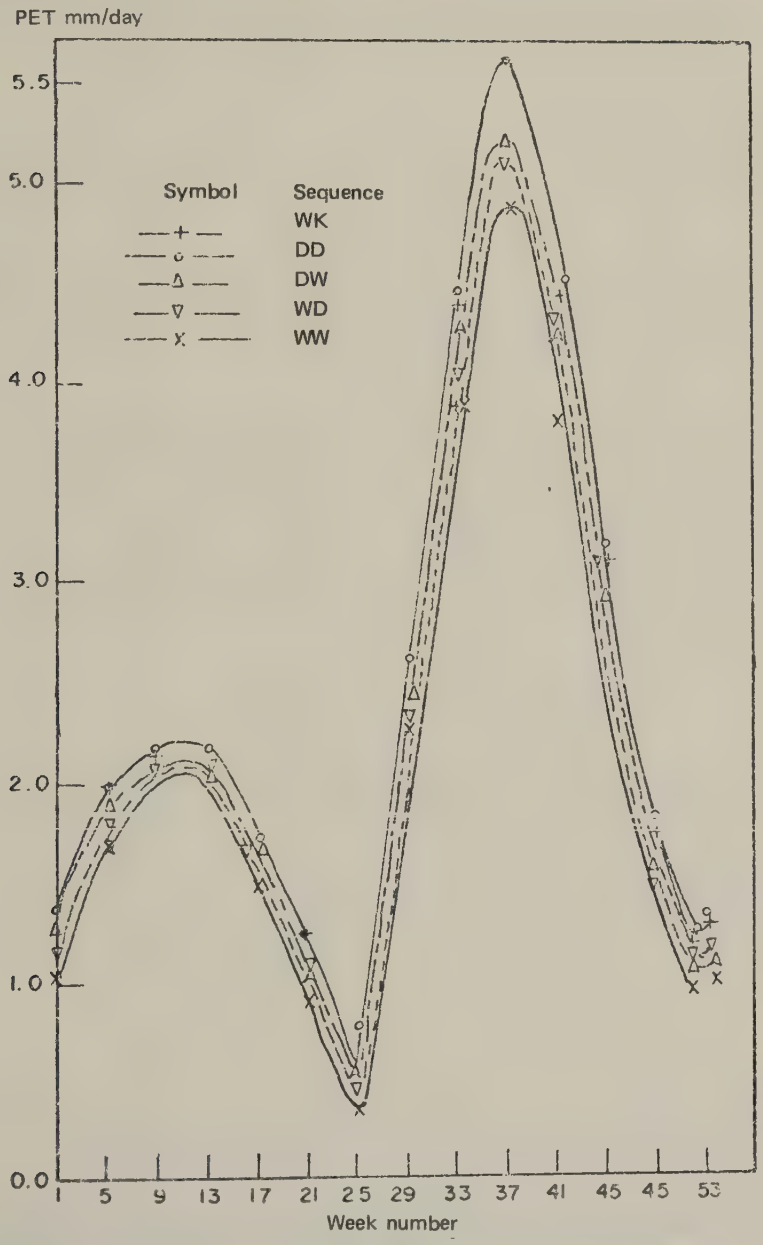

FIGURE 4. Comparison of various PET sequences (actual data).

The R^2 values for WK and DD sequences were 0.62 and 0.63, respectively, whereas for other sequences these range from 0.51 down to 0.19. Because of the low values of R^2 for weekly variances, it was not appropriate to use polynomial equations in simulation model. However, this analysis indicated that the time of the

year and sequences produced based on the criteria of a dry day or a wet day are necessary for simulation for daily time intervals.

The PET simulation program

The simulation program for the PET consists of a MAIN program that includes the following two sub-mains and sub-routines:

1. MAINWK: Which simulates the WK-sequence, by calling a sub-routine WKPETI, for the given number of years. The WKPETI calls NORMAL where PET for each week is simulated from a series of random numbers ranging from 0.0 to 1.0 generated by RAND 1.

2. MAINSQ: Which simulates the DD, DW, WD and WW sequences, by calling the subroutines DDPETI, DWPETI, WDPETI and WWPETI respectively, for the given number of years. Each of these subroutines simulates the respective sequence in a similar manner as described for WKPETI above. The DDPETI is called for each week but the other sub-routines are called according to the probability of occurrence of the respective sequences as determined by a random number generated by RAND 2.

3. OUTP: Prints simulated sequences separately.

4. STPARM: Calculates the statistical, parameters like means, variances and skewness coefficients for each week of simulated PET sequences.

A complete set of computer program is available at the Library and Regional Computer Center, AIT.

SUMMARY AND CONCLUSIONS

The simulation results

The simulated sequences of PET for ten, twenty, and fifty years were obtained. One year's simulated data out of fifty years of WK-sequence, selected at random, is compared with one year (1914-15) actual data from WK-sequence in Table 6. The minimum value of PET in actual data is 0.69 mm/day for 24th week whereas the minimum value in the simulated is 0.55 mm/day for 25th week. The maximum values for actual and simulated are 5.83 mm/day and 5.5 mm/day for 39th and 40th weekly,respectively.

Table 7 presents parameters e.g., means and variances for fifty year's data of PET sequences. The minimum mean values of 0.60 mm/day with variance of 0.005 for WK-sequence, 0.61 mm/day with variance of 0.005 for DD-sequence, 0.52

TABLE 6. Daily mean evapotranspiration for each week of WK-Sequence from actual data (1914-15) and simulated data of one year out of 50-years simulation.

Week	Data (mm/day)		Week	Data (mm/day)	
	Actual	Simulated		Actual	Simulated
1	1.29	1.32	30	3.41	3.11
2	1.35	1.50	31	4.02	3.27
3	1.48	1.80	32	4.47	4.40
4	1.78	1.75	33	4.80	5.45
5	1.84	1.76	34	4.93	4.87
6	2.00	2.32	35	5.38	5.06
7	2.11	1.91	36	5.73	5.17
8	2.06	1.94	37	5.59	4.69
9	2.15	2.24	38	5.55	5.21
10	2.11	2.42	39	5.83	4.74
11	2.02	2.25	40	4.74	5.55
12	2.11	1.95	41	4.57	4.63
13	2.11	2.13	42	4.35	3.87
14	1.89	2.14	43	4.06	4.02
15	1.82	1.43	44	3.79	2.98
16	1.77	1.82	45	3.36	3.17
17	1.76	1.47	46	2.90	3.00
18	1.72	1.69	47	2.47	2.43
19	1.56	1.21	48	2.17	2.45
20	1.26	1.54	49	1.85	1.30
21	1.12	1.39	50	1.41	1.07
22	1.08	1.14	51	1.08	1.35
23	1.01	0.77	52	1.34	0.76
24	0.69	0.80	53	1.46	1.21
25	0.71	0.55			
26	1.12	0.88			
27	1.80	1.49			
28	1.98	2.20			
29	2.56	2.43			

mm/day with variance of 0.005 for WK-sequence, 0.61 mm/day with variance of 0.005 for DD-sequence, 0.52 mm/day with variance of 0.006 for DW-sequence, 0.47 mm/day with variance of 0.002 for WD-sequence and 0.42 mm/day with variance of 0.001 for WW-sequence are for the 25th week of actual data whereas the corresponding minimum mean values of 0.63 mm/day with variance of 0.003 for WK-sequence, 0.66 with variance of 0.005 for DD-sequences, 0.66 mm/day with variance of 0.003 for DW-sequence, 0.50 mm/day with variance of 0.001 for WD-sequence and 0.31 mm/day with variance of 0.0004 for WW-sequence are also

TABLE 7. Statistical Parameters of PET. Sequences Each Week (From 50 yrs. Simulated Data)

	Sequences									
	WK		DD		DW		WD		WW	
Week	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
1	1.41	0.018	1.40	0.014	1.48	0.073	1.32	0.012	0.28	0.019
2	1.60	0.029	1.62	0.026	0.0	0.0	1.96	0.031	0.0	0.0
3	1.75	0.028	1.72	0.016	1.72	0.043	1.59	0.005	0.0	0.0
4	1.85	0.016	1.85	0.022	2.01	0.038	0.0	0.0	0.96	0.000
5	1.98	0.011	1.97	0.017	1.98	0.007	1.81	0.001	1.04	0.005
6	2.09	0.034	2.05	0.019	2.07	0.225	1.64	0.051	1.26	0.0
7	2.12	0.027	2.10	0.027	0.0	0.0	1.89	0.036	0.0	0.0
8	2.15	0.024	2.19	0.024	2.24	0.005	1.93	0.067	1.48	0.0
9	2.19	0.023	2.21	0.020	2.52	0.005	1.99	0.007	0.0	0.00
10	2.20	0.033	2.21	0.034	2.30	0.074	1.97	0.071	0.0	0.0
11	2.20	0.019	2.18	0.021	2.16	0.079	1.97	0.031	1.65	0.002
12	2.16	0.021	2.16	0.028	2.21	0.012	2.07	0.051	1.61	0.307
13	2.08	0.024	2.11	0.031	2.10	0.014	1.98	0.003	1.75	0.000
14	2.02	0.012	2.02	0.014	1.97	0.041	1.89	0.064	1.70	0.101
15	1.96	0.049	1.99	0.035	1.90	0.042	1.82	0.015	1.82	0.034
16	1.85	0.014	1.84	0.014	1.86	0.013	1.76	0.013	1.71	0.000
17	1.72	0.024	1.76	0.020	1.69	0.049	1.69	0.046	0.0	0.0
18	1.62	0.028	1.61	0.036	1.61	0.041	1.56	0.042	1.49	0.036
19	1.47	0.021	1.51	0.017	1.54	0.043	1.38	0.015	1.36	0.036
20	1.37	0.028	1.40	0.018	1.45	0.043	1.22	0.015	1.61	0.047
21	1.27	0.030	1.24	0.033	1.32	0.025	1.07	0.013	1.12	0.009
22	1.08	0.021	1.12	0.017	1.11	0.020	1.00	0.019	0.95	0.003
23	0.95	0.001	0.96	0.013	0.98	0.18	0.78	0.015	0.71	0.020
24	0.77	0.007	0.81	0.004	0.78	0.010	0.64	0.003	0.54	0.000
25	0.63	0.003	0.66	0.005	0.66	0.003	0.50	0.001	0.31	0.000
26	0.76	0.018	0.78	0.020	0.80	0.006	0.49	0.10	0.62	0.000
27	1.45	0.053	1.48	0.042	1.31	0.057	1.19	0.059	1.24	0.074
28	2.17	0.088	2.21	0.072	2.12	0.087	1.91	0.041	1.65	0.093
29	2.77	0.077	2.81	0.093	2.66	0.199	2.51	0.092	2.34	0.000
30	3.41	0.131	3.35	0.143	3.40	0.067	3.13	0.042	2.85	0.8
31	3.78	0.155	3.80	0.134	3.91	0.060	3.67	0.129	3.07	0.251
32	4.30	0.113	4.31	0.99	4.39	0.245	4.03	0.025	3.73	0.072
33	4.65	0.225	4.69	0.264	4.51	0.261	4.49	0.213	3.93	0.500
34	4.87	0.138	4.96	0.113	4.88	0.401	4.66	0.368	4.24	0.0
35	5.18	0.83	5.12	0.098	5.24	1.04	4.90	0.059	4.44	0.011
36	5.27	0.181	5.30	0.215	5.42	0.269	5.08	0.214	0.0	0.0
37	5.24	0.269	5.34	0.183	5.54	0.166	5.17	0.404	4.69	0.503
38	5.20	0.155	5.29	0.163	5.03	0.410	5.07	0.280	5.59	0.0
39	5.09	0.205	5.27	0.303	5.15	0.086	4.90	0.613	4.39	0.38
40	4.86	0.112	4.93	0.092	4.93	0.219	4.51	0.148	4.41	0.072
41	4.63	0.141	4.62	0.094	4.60	0.199	4.27	0.077	4.00	0.183
42	4.30	0.067	4.35	0.131	4.36	0.127	4.18	0.197	3.77	0.130
43	3.99	0.85	4.01	0.078	3.98	0.175	3.78	0.181	3.47	0.092
44	3.55	0.074	3.66	0.065	3.68	0.077	3.49	0.084	2.98	0.063
45	3.14	0.052	3.15	0.067	3.14	0.050	2.89	0.073	2.72	0.089
46	2.65	0.051	2.74	0.052	2.88	0.039	2.47	0.039	2.52	0.026
47	2.25	0.080	2.38	0.070	2.35	0.081	2.08	0.045	1.68	0.038
48	1.92	0.058	1.96	0.029	1.94	0.035	1.66	0.075	1.41	0.066
49	1.60	0.028	1.62	0.038	1.70	0.059	1.40	0.041	1.26	0.049
50	1.33	0.014	1.38	0.020	1.32	0.036	1.13	0.062	1.34	0.0
51	1.20	0.010	1.22	0.018	1.24	0.006	0.96	0.017	0.88	0.002
52	1.15	0.024	1.20	0.020	1.16	0.029	1.02	0.014	0.84	0.0
53	1.30	0.028	1.27	0.033	0.0	0.0	1.11	0.007	0.91	0.00

for the 25th week of simulated data.

Similarly, the maximum mean values, from actual data, are of 5.63 mm/day with variance of 0.269 for WK-sequence, 5.65 mm/day with variance of 0.212 for DD-sequence and 4.90 mm/day with variance of 0.23 for WW-sequence for 37th week, 5.29 mm/day with variance of 0.212 for DW-sequence are for 39th week and 6.88 with variance of 0.76 for WD-sequence for 35th week whereas the corresponding maximum mean values, from simulated data, are 5.27 mm/day with variance of 0.181 for WK-sequence of 36th week, 5.34 mm/day with variance of 0.183 for DD-sequence, 5.54 mm/day with variance of 0.166 for DW-sequence and 5.17 with variance of 0.404 for WD-sequence of 37th week and 5.59 mm/day with variance of 0.004 for WW-sequence, for 38th week.

A pictorial comparison of weekly means as calculated from actual data, polynomial equations and 50 years of simulated data is presented in figure from 4.5 to 4.9 for WK, DD, DW, WD and WW sequences, respectively.

Limitations of Study

This study was subject to a number of limitations regarding the development and tuning of the simulation model of PET. Neither field nor laboratory experimental daily evapotranspiration data from the study area was available to compare with the simulated data. Based upon the conclusions drawn through the recent studies conducted in Pakistan and similar locations in United States (Early[16] Gill[18], Jensen[23]) the modified Penman equation was used to estimate the daily potential evapotranspiration for developing the simulation PET model.

Secondly, although the meteorological data used in the Penman equation were gathered for 56 years, some of the data inputs like actual sunshine hours and relative humidity were not continuously recorded. The missing values were estimated from the available record using the mean values from the week in question.

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MODELO SIMULADO DE EVAPO-TRANSPIRACION PARA CAÑA DE AZUCAR IRRIGADO EN EL PUNJAB DE PAKISTAN*

A. C. Early y S. Khan**

RESUMEN

Un modelo simulado de computadora fué desarrollado para el medio potencial diario de evapo-transpiracion (PET) en base semanal. El dato del potencial diario evapo-transpiracion se calculó usando la equación Penman modificada desde 56 años de datos hydrometeriologicos historicos recogidos en una estación situada en el area de estudio. El modelo fue desarrollado principalmente basado en la asunción o en la suposición que poco cambio ocurre durante la semana. Pero durante el desarrollo del modelo nos dimos cuenta que la ocurrencia de dias aislados de lluvia o de una serie de dias lluviosos era importante, pero que la cantidad de lluvia no tiene efecto significante en la PET.

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Un importante resultado de este estudio es que la PET es un variable al tuntun para cualquier semana del año, es normalmente distribuido, y que el medio semanal de estas distribuciones tiene una relación determinativa con las respectivas semanas del año. El modelo hace uso de estas propiedades de la PET para generar datos para una cantidad de años. Es bastante flexible para circundar las variaciones de la temporada o estación en que ocurren durante la semana debido a lluvias. Para estudiar una cosecha completa de sistema de producción, este modelo PET puede usarse como parte o componente de un modelo ambiental que cubre toda cosecha, describiendo la entrada "input" de lluvia, evapo-transpiración y variaciones con fondo de humedad de tierra, como una base para la distribucción o repartimiento de irrigación de agua para intensificar la producción de caña dulce de azúcar.

PERMANENT FURROWS AS AN OPTION OF MINIMUM TILLERING FOR SUGARCANE

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ABSTRACT

The sugarcane planting process in wide base at 1.70 m spacing permits soil preparation only in the strip occupied by ratoon line when reforming the sugarcane area. When furrows are reopened in the same place as previous furrowing preceded by the destruction of ratoons and subsoiling operations, the culture assumes the characteristics of plantation in permanent furrows. Reductions of costs with field operations besides cultural remains and fertilizer profits, is advantageous to the new formed culture.

INTRODUCTION

The sugarcane planting through wide base furrowing method (Fernandes *et al*[5]) with spacing of 1.80 m measured in the center of furrows, permits the traffic of transport vehicle wheels and agricultural machines only in the interlines, therefore avoiding, at least minimizing, the soil compaction in the strip,occupied by ratoons lines.

Still according to considerations by Fernandes[2], planting in 1.70 m spacing in the same furrowing system permits the joint operations of mechanical harvest and transport of sugarcane by vehicles directly from the cultural area.

This spacing may be narrow for double-wheeled vehicles during planting due to the 90-100 cm furrow opening. However, sugarcane rows in the fifth or sixth harvest are not wider than 50-55 cm.

The lateral subsoiling operations such as tillering of ratoons and deep applications of fertilizer permit the preservation of a soil strip with 70-80 cm width under adequate conditions for better development of the root system. Consequently, soil compaction will not be greatly responsible to yield reductions in successive sugarcane harvests. As such the number of harvests in each planting cycle can be increased to 5 or 6, compared with the conventional 3 or 4 harvests.

On the other hand, the well differentiated and alternated strips representing rows and interrows of ratoons, induce the possibility of reconstruction only in those strips occupied by root system, when the area is reformed.

Thus, interrows that received compaction by vehicle in successive harvests remain under those physical conditions during subsequent agricultural cycles. At same time, the traffic control and minimum tillering for sugarcane is obtained.

Sugarcane planting at 1.70 m spacing results in 782 m less of furrows per hectare. Therefore, almost one kilometer is not run over by machines, implements and transport vehicles in each cultivated hectare compared with furrowing at 1.50 m distance.

EXPERIMENTAL PROCEDURE

Sugarcane planting in wide base furrows

Elimination of ratoons was made through traditional process, using one or two heavy harrow operations or one superficial plowing, followed by slight harrowings.

Corrective application, if needed was made over the area before the elimination of ratoons. Another option was to apply deeply through additional device.

Soil preparation

After cleaning the area of the remaining ratoon, all of the other activities follow the recommendations for wide base furrows, beginning with soil preparation. The plowing, subsoiling or harrowing operations, are substituted for only one subsoiling operation.

The fundamental difference lies in the fact that subsoiler implement operate in strips not more than 70-80 cm wide and 1.70 m apart, measured from the centers.

For each strip three rods in the subsoiler were used. If small flies were applied in the lower extremity of only two rod, 60 cm was enough for each strip.

Furrowing

Wide base furrows, 30 cm interval opening and 1.70 m spacing were used exactly on the subsoiled strip.

Fig. 1 shows an implement for wide base furrows. Only simple alterations in common implement are sufficient.

As can be observed, three aspects are important: a) subsoiler flies are made and adapted following a horizontal line in its inferior plane from the beak to the posterior extremity. This will prevent the earth from penetrating into

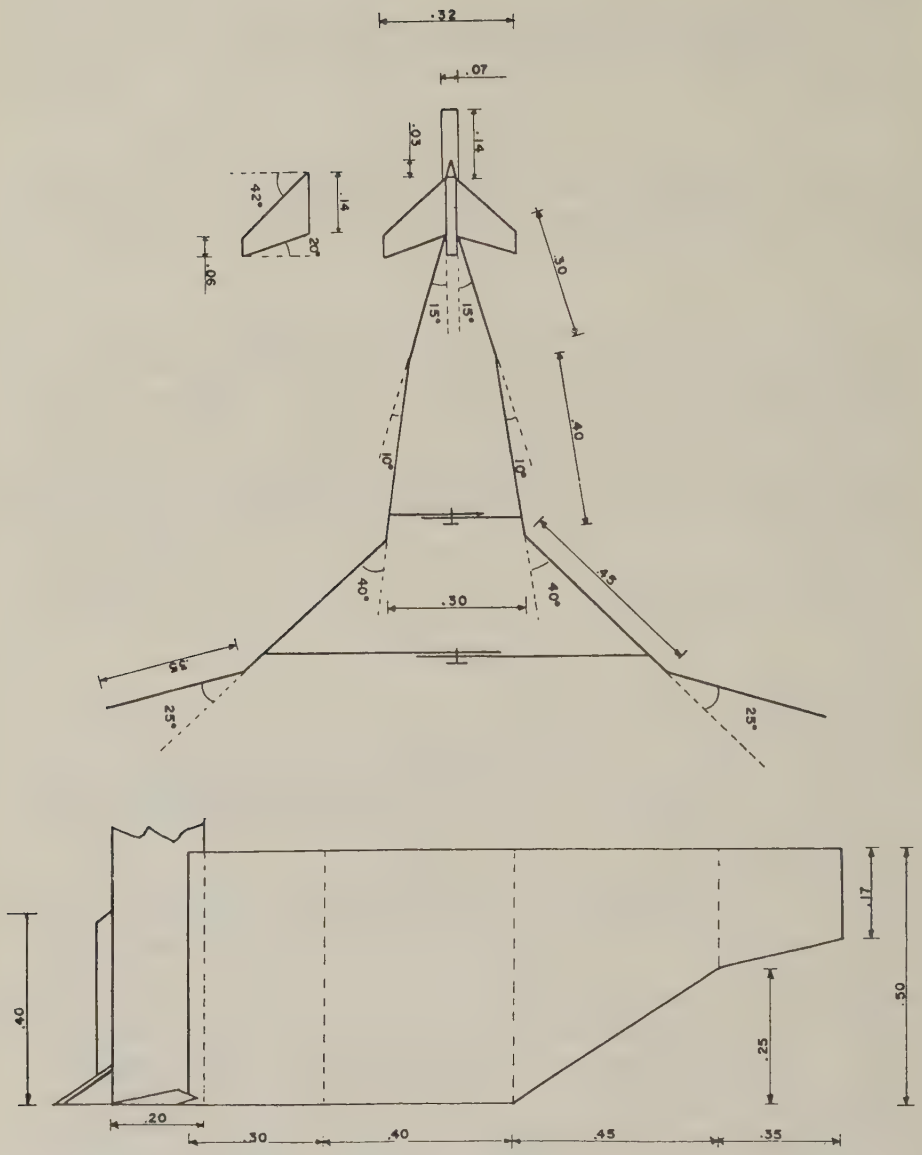

FIGURE 1. Top and lateral views of wide base furrower.

the furrow during the work; b) for a more efficient work, the soil must be prepared until a profile below the inferior level is reached by the implement; and c) a small fly attached in the inferior part of the furrower rod 32 cm wide completes soil decompaction before furrowing.

Planting and fertilizer application were done simultaneously with furrowing.

Planting

The advantages of conventional furrowing and spacing method begins with distribution of sugarcane seeds in the furrows. Vehicles pass only in interlines. Machine with implement covering the stalk and applying herbicides does not pass inside the furrows.

Cultural tillering of ratoons

Larger producers who prefer to apply fertilizers through machines to achieve a higher operational work do not depend on making it before the beginning of the bridding. The vehicle does not damage the growing plants when passing in the interrows.

Subsoiling operations recommended for sugarcane planting in single furrows in both sides of ratoon are also convenient here to provide better physical conditions of soil near sugarcane rows. During this tillering operation, a deep fertilizer application is possible.

Unlike the agricultural practices in conventional planting, decompaction in interlines of wide base planting does not occur, owing to two main reasons: a) the rain due to the difficulty in penetrating the compact area of interrows flows to the rows, where the fetilizers and most of root system are; b) during the harvest time, the transport operation is facilitated by the hard soil especially under rainy condition.

Harvest

For mechanized harvesting of cane, the preconceived spacing presents a perfect syncronization between harvester and transport vehicle, both riding in the inter-lines, (Fig. 2).

Sugarcane Replanting in Wide Base

Inspite of the advantage presented by wide base furrows, several operations will have to be executed in the period of replanting, following the agricultural characteristics of sugarcane, such as ratoon elimination soil corrective application, restoring better soil physical condition, furrowing and planting. However, it is convenient to emphasize that these operations will be made only in the strips 70-80 cm wide, where the first furrowing was and will be processed as follows:

1) *Destruction of ratoons*

Using minimum plowing or heavy harrowing to eliminate remaining ratoons would eliminate the marks of rows after sugarcane harvest. Then this work will be substituted by one of the following operations:

a) with herbicide application in adequate dosages and not resulting in

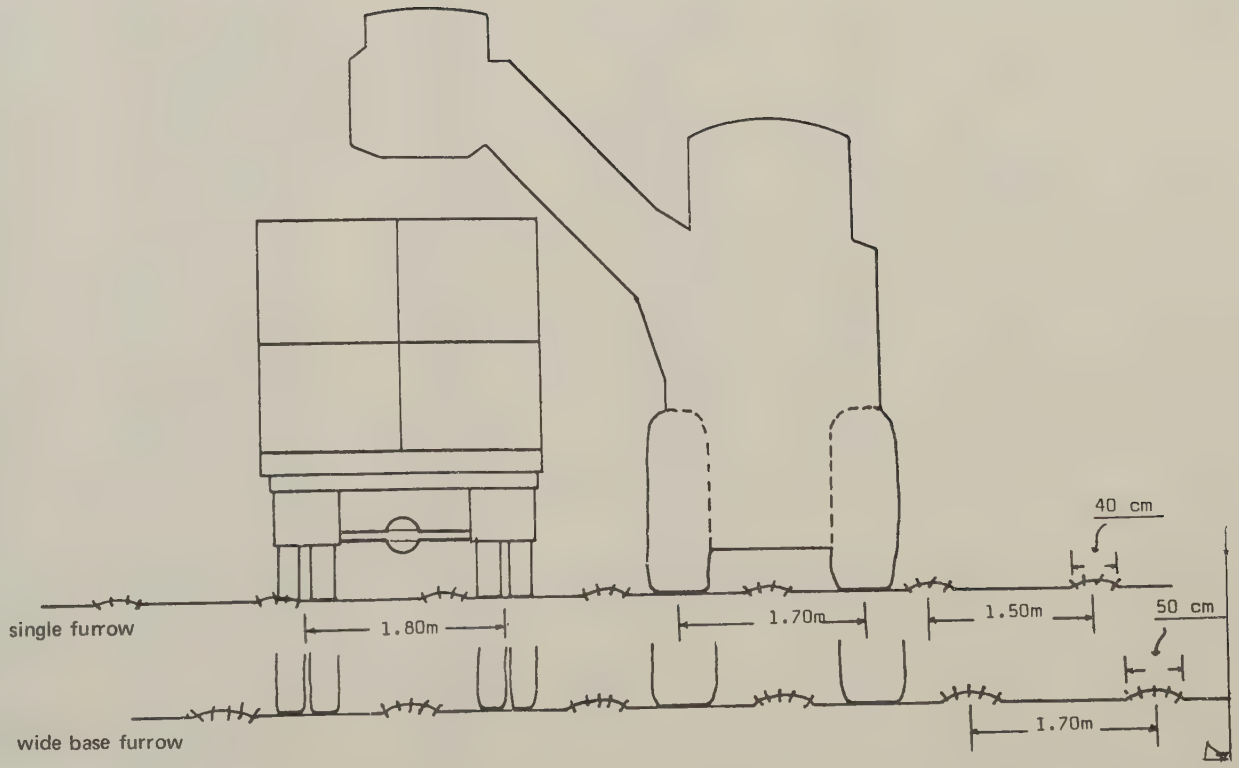

FIGURE 2. Schematic presentation of transport vehicle and harvester positions in the single and wide base furrows in the 5th harvest.

residual effects in soil, therefore, a maximum budding of ratoons is expected;

b) using modified rotavator (Fernandes[2]).

Any of both modification can be executed before or after operations of items 2 and 3.

2) *Lime application*

Similar to the process used in the last planting, the lime application can be distributed to total area or in depth during the subsoiling operation

3) *Subsoiling, furrowing, planting and cultural tillerings*

These operations will follow the same methodology of previous planting. Therefore new wide base furrows will have adequate physical conditions through subsoiling in same marked lines of sugarcane, which are still visible.

4) *Harvest*

For sugarcane harvest and transport operations in all cycles of each replanting period, the traffic of vehicles and agricultural machines in the area with sugarcane will be directed only to the interlines.

DISCUSSIONS AND CONCLUSION

Despite being an operational technology that requires many planting cycle for an adequate interpretation of the several agricultural aspects involved, the present considerations permit to conclude that there is a series of advantages over sugarcane planting through the traditional method. The localization of furrows in the same strip of furrowing of previous planting offers the opportunity of better profit from cultural remains, such as organic and fertilizer residual. The rain or water from sprinkling irrigation, due to the difficulty of infiltration in compacted interlines, will flow to the row where the greater proportion of the root system can be found. Characterized by intercalated stripes concerning compaction aspect, this process will represent an option to the planting in declivous areas to control the erosion. The traffic of vehicles and agricultural machines only in interlines eliminates or minimizes the damage to the ratoons due to the absence of soil compaction in sugarcane rows and represent the factor of fundamental importance as field technology.

Operational aspects

Destruction of ratoon through herbicides or rotavator modified to work only in strips of 60-70 cm will depend on economic factors or operational efficiency. The planting method in wide base furrows does not require introduction of new agricultural implements, but only little modifications in conventional

implements.

Minimum tillering aspects

The work of the rotavator in strips 60-70 cm wide eliminating ratoons will contribute to the incorporation, through cultural remains and applied lime. Several pre-planting operations carried through traditional implements (subsoiling in total area, plowing and harrowing) will be substituted by only one subsoiling operation, the implement operating in a 70-80 cm wide strip, corresponding to the row occupied by the sugarcane. The recommended cultural tillerings for ratoons, such as deep fertilizing in both sides of sugarcane lines and the tillering of interlines, have already been executed through only one operation; simultaneous application of herbicides is being studied when aereal application proves to be impossible.

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SURCOS PERMANENTES COMO OPCION DE PROFUNDIDAD MINIMA PARA SIEMBRA DE CAÑA DE AZUCAR NOTA PREVIA

Jose Fernandez

RESUMEN

Al reformar un area, el proceso de siembra de caña de azucar en base ancha, a intervalos de 1.70 m permite la preparacion del terreno en la hilera ocupada por retoños unicamente. Al reabrir Sucros previos, precedido por la destruccion de retoños y subsolacion, el cultivo asume caracteristicas de siembra en sucros pernamentes. Las ventajas de los nuevos cultivos seran la reduccion de costo en

operacion del campo, ademas de cultivos permanentes y beneficiosos para la fertilizacion.

SEMI-MECHANIZED SUGAR HARVESTING SYSTEMS FOR A DEVELOPING COUNTRY

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ABSTRACT

The population growth rate of developing countries is currently 2.4% per year. Many of these countries are already experiencing widespread unemployment. The growth in GNP for most developing countries, South Africa included, is too low to rectify existing unemployment situations appreciably, with little hope of catering to the expected future population increase. Everything possible should thus be done to increase job opportunities, especially in the rural areas of these countries.

For various reasons, manual harvesting of sugarcane might become less attractive to laborers. Mechanical alternatives should therefore be available for use when labor becomes unobtainable. Developing countries should not, however, indulge in highly mechanized farming systems, but should strive for the optimum combination of labor and equipment to suit their particular circumstances.

Towards this end the Experiment Station of the SASA has developed several cane cutters which, when integrated into suitable cane handling systems, allow for a gradual increase in the degree of mechanization. The design of all of these machines is simple. Maintenance and operation is well within the capabilities of ordinary tractor drivers. A number of semi-mechanized harvesting systems, incorporating these cutters, have been evaluated. Labor productivity can be increased over a range from 4.5 to 15.0 t/man-day. Harvesting costs can be kept reasonably low, and in the current South African situation they should be much lower than those of completely mechanized chopper harvesting systems.

INTRODUCTION

South Africa is a developing country with a black population of 19.6 million, 70% of which live in rural areas. The average annual growth rate of this section of our population is 2.9% compared with 1.2% for developed countries (Wyndham[12]).

Based on present predictions, a population explosion which may be more severe than almost anywhere else in the world is expected. Half of the present black population is less than 16 years old.

Due to a general slowdown in the economy, unemployment is already a serious problem. To rectify this situation and to take care of the increasing labor supply, it is estimated that 500,000 new jobs per year will be required throughout the nineties. For this requirement, an annual growth rate of more than 6% in GNP would be needed. Present prospects are not anywhere near this figure. In fact, the increase in the GNP from 1973 to 1978 was only 2.5% per year (Ardington[8]). Unemployment is thus likely to be a feature of the foreseeable future, and agriculture should therefore be assured of a plentiful supply of labor as long as there is a will to work. There is considerable incentive for the country and the sugar industry to encourage young South Africans to seek employment in agriculture.

In these circumstances it is anomalous that there should be a strong trend towards mechanization in traditionally high labor-intensive fields such as mining and agriculture. In 1974 the gold mining industry announced a R90 million research program into new techniques of mechanization (Anon[5]). Sales of tractors more powerful than 60 kW increased from 3 to 8% of the total tractor market from 1971 to 1976. Tractors of 150 kW are becoming a common sight on South African farms. Undoubtedly, mechanization may lead to outstanding increases in food production, but the particular situation demands the development of efficient labor-intensive techniques. Emulation of the super-mechanized farming systems of countries such as the USA and Australia, where agricultural labor is scarce, should not be done. Labor-intensive production methods do not however preclude the use of machinery. The optimum combination of labor and equipment should be considered.

Experience in many parts of the world has shown that sophisticated machinery is often introduced to developing countries without the precautions being taken to ensure that operators are adequately trained, that necessary after-sales maintenance will be carried out satisfactorily, and that the standard of management will be sufficient to keep the total system running well. Without these precautions being taken, the situation usually ends in disaster. It is easy to agree with Burleigh[9] that the economic and social justifications for the use of combine harvesting systems in sugarcane are questionable since there is a large population of unemployed or underemployed laborers.

It must be accepted that manual cane cutting and loading is an onerous and arduous task. Experience in most overseas cane-growing countries indicates that no matter how high wages may rise, cane cutting will eventually become an unacceptable way of earning a living. Our steadily rising standards of education will make this development most likely to occur. Thus, despite the prospect of a large available labor force, it would be dangerous to rely on it entirely for the harvesting

of our sugarcane crop.

In 1973 it was decided at the Experiment Station to develop semi-mechanized, low-cost harvesting systems for the South African sugar industry. These systems were to be compatible with existing manual harvesting and handling methods, and were to provide mechanical alternatives for all facets of the harvesting operation. Additionally, they were to be applicable on slopes up to 30% and on fields not carefully prepared for mechanized operations. The machines would have to be simple enough to be handled and maintained by ordinary tractor drivers and mechanics. Only wholestalk cutters were to be considered because practically all South African sugarcane is harvested and transported as whole stalks.

MACHINES DEVELOPED

Full descriptions of the various cutters that were developed can be found in Annual Reports of the Experiment Station from 1973/4 to 1978/9 [1,2,3,4,5,6,7] and in papers by Pilcher and van de Merwe[10] and by van der Merwe *et al*[11]. In chronolgocial order of development, these machines were:

Gobbler cane harvester

The intake of this machine is based on the chopper harvester principle so that recumbent cane can be accommodated. After topping, the cane is pushed forward and cut at the base. It is then conveyed horizontally to the rear. Instead of being chopped at this stage, the stalks are gripped at the butt end by special ejector rolls and thrown into a bin. The bin has a capacity of 200 kg of cane and this load is dropped as a loose bundle onto the ground for subsequent mechanical loading. This procedure eliminates the necessity for push-pilling. The machine has a low center of gravity and is side-mounted on a conventional tractor (Fig. 1). Two prototypes were built and tested in 1973 and 1974. Disposal of the bundles of cut cane from this side-mounted machine proved to be a problem, however, and it became necessary to consider adapting the Gobbler principle to a machine which straddled the row being cut. Further development of the Gobbler has been shelved pending the results of a number of other projects.

Sasec cane cutter

Various models of the Sasex cane cutter were developed from 1974 to 1977. This machine is side-mounted onto any agricultural tractor of 50 kW or more and is carried on the 3-point hitch (Fig. 2). The Sasex can be hitched or detached in a few minutes and the tractor can then be used for other duties. Cane is topped, base cut down and laid down in a 'sausage' windrow. Depending on row width and tractor wheel spacing, a complete field can be cut and the windrows of cane left for subsequent manual stacking, bundling or crosswindrowing. Latest modifications include a more reliable hydraulic drive to the base cutter which aids cutting

FIGURE 1. Gobbler cane harvester

FIGURE 2. Sasex cane cutter in its simplest form

in poorly prepared fields. In its simplest form, the Sasex can handle recumbent burnt cane yielding up to 110 t/ha. Modifications are available to allow cutting of heavier, more recumbent cane.

Edgecombe cutter

The first prototype of the Edgecombe cutter was built in 1976 to overcome

the greatest shortcoming of the side-mounted Sasex. When operating on steep slopes or in unsuited row spacings the Sasex tended to run over cane which had already been cut. At first the Edgecombe was basically a Sasex mounted on the front of a tractor. In 1977 the machine was built on the rear of a two-wheel drive tractor with reversed controls (Fig. 3). During its development it was found that the croplifters, as used on some of the Sasex machines, were more of a hindrance than a help in a recumbent cane. These were removed and drums were fitted around the base cutter shafts. These did an excellent job of disentangling the cane and drawing the crop to the base cutters. The twin base cutters were driven hydraulically. Cane from two rows was topped, base-cut and left in a single 'sausage' windrow Row spacings of 1.0 to 1.5 m could be accommodated. Because the Edgecombe machine straddled the cane rows, it could cut a cane face in any direction and was also able to open up a field without damaging any cane on either side of the machine. Heavy, recumbent burnt cane (up to 140 t/ha) can be handled and the Edgecombe can also cut fire breaks in green cane yielding up to 110 t/ha.

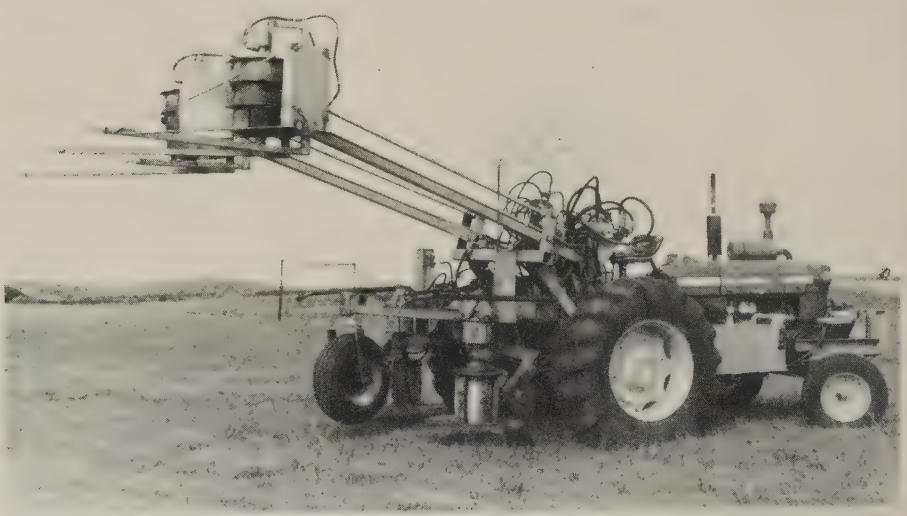

FIGURE 3. Edgecombe cane cutter

Midway cutter

This is another 'sausage' type machine developed in 1978 as a further option for growers whose requirements were not adequately met by the Sasex and the Edgecombe. The Edgecombe is a relatively complicated machine to build and the Sasex can only be used with certain row spacings, and where the crop is neither too heavy nor recumbent. The hydraulically driven base cutter of the Midway is mounted between the front and rear wheels of a tractor (Fig. 4). It has a rotating drum arrangement similar to that of the Edgecombe. The front right hand wheel of

the tractor was moved inwards by means of a spacer. The base cutter has an anti-clockwise rotation and the 'sausage' is placed beneath the tractor. The operator has an excellent view of the base cutter. The topper is mounted in front of the tractor to allow for the installation of a bin in which to catch the tops. This innovation could help to reduce considerably the amount of extraneous matter in consignments of cane. Burnt recumbent cane yielding up to 130 t/ha can be handled by the Midway.

The machines described thus far are all built into or attached to standard wheeled agricultural tractors. Maintenance and repairs can be done in normal farm workshops. Hydraulic pumps and motors are available on an exchange basis so that any breakdowns should be of short duration.

Cutting rates will depend on field conditions. The Sasex and Midway cutters are recommended for growers harvesting up to 100 tons per day. The Edgecombe can handle 200 tons per day and can cut as much as 60 tons per operating hour. All three machines can operate on slopes up to 30%.

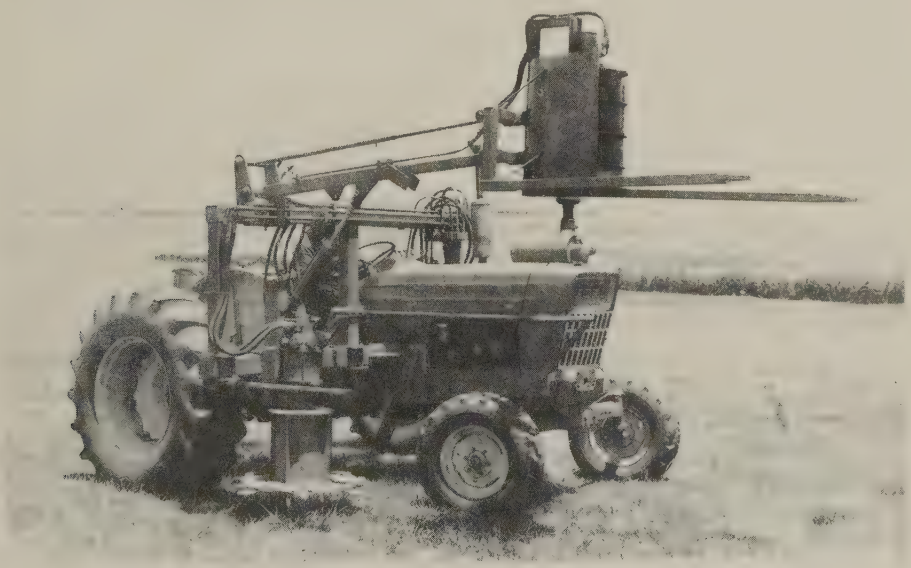

FIGURE 4. Midway cane cutter

Plans of the Sasex, Edgecombe and Midway cutters are available to cane growers. A number of engineering shops are prepared to build machines on order.

HARVESTING SYSTEMS

Manual cutting and stacking is the most common harvesting system being used in South Africa. Self-loading trailers are used to pick up and transport stacks

of four to five tons to a transloading zone, or directly to the mill. This is a very flexible system with one self-loading trailer capable of handling 75 t/day. Each trailer and its crew is completely independent and can haul stacks when convenient without any assistance from other machines.

Manual cutting and windrowing with mechanical push-pile loading is popular in the Natal Midlands and Eastern Transvaal. As what happens in other countries, large quantities of soil are delivered with the cane to the mill when pushpile loading is practiced. Ash (soil) percent dry matter of pushpiled cane from a number of large estates was monitored in 1978. The average was 5.5% and individual samples exceeded 20%. A mechanical loading system entails the combination of a loader and a trailer. One cannot operate without the other and growers cutting 50 t/day or less may find that loader waiting time can be as much as 70% of the total time spent in the field.

Instead of mechanizing the loading operation, the cutting operation can be mechanized. The effort of retrieving the cane from the sausage windrows is less physically demanding than manual cutting if machines such as the Sasex, Edgecombe or Midway are used. Labor to perform this task should still be available therefore even when manual cane cutters are not.

Handling systems which include an increasing degree of mechanization are available to meet the demands caused by a dwindling labor supply. The systems listed in Table 1 were evaluated by the Experiment Station during 1977 and 1978 on our La Mercy Farm. Commercially grown cane was used in this project and it was harvested at rates between 50 and 100 tons per day. The variety was NCo 376 giving an average yield of 110 t/ha. It was planted in rows 1.5 m apart. The productivity shown in Table 1 for cane cut mechanically, may be compared with various averages for manually-cut cane in the South African industry. These are 2.7 t/man-day for cutting and stacking and 3.6 t/man-day for cutting and windrowing in the industry as a whole, and 4.5 and 6.0 t/man-day for the same two systems, respectively, under similar conditions on neighboring estates.

The labor requirements for the various semi-mechanized systems shown in Table 1 include all field personnel such as gleaners and loaders or assistants to the cutters but they exclude the machine operators themselves.

The first system comprised stacking the cane from the 'sausage' windrows manually. Tops and other extraneous matter which may have been in the windrows were thus generally left in the field. This resulted in the cleanest possible cane with a minimum of soil being delivered to the mill. Productivity was 7.5 tons/man-day.

By stacking mechanically from small manually prepared bundles, the productivity per man-day was increased to 9.8 tons in system 2. For this operation a loader of the 'Bell' type was required. This South African loader is extremely maneuverable and can stack cane more efficiently than normal slewing-type loaders.

Changing from self-loading to box-type trailers, and loading mechanically from manually prepared windrows, as in system 4, gave results similar to those obtained with system 2, viz 10 tons/man-day. Note that when dealing with recumbent cane, topping during windrowing was required to remove the tops missed by the topping device on the cutting machine (System 3). This reduced productivity to 6 tons per man-day.

By stacking mechanically with a Bell loader directly from the sausages, as was done in system 7, productivity was increased to 14.9 t/man-day. Again there was a reduction in productivity when manual topping or cleaning of stacks was required (Systems 5 and 6).

The final system to be evaluated was that of mechanical loading by Bell loader from the sausage into box trailers (System 8). While waiting for a trailer to return from the loading zone, the loader prepared 'windrows' of cane. This resulted

TABLE 1. Labor requirements for various handling systems of burnt sugarcane cut mechanically by machine such as the Sasex, Edgecombe and Midway.

System	tons/man-day
Manual stacking, self-loading trailers	7.5
Foaming small bundles manually, mechanical stacking* self loading trailers	9.8
Manual windrowing and topping**, mechanical loading into box trailers	6.0
Manual windrowing, mechanical loading into box trailers	10.0
Mechanical stacking* after manual topping** in the sausage, self-loading trailers	6.2
Mechanical stacking*, some manual cleaning of stacks, self-loading trailers	11.7
Mechanical stacking*, self-loading trailers	14.9
Mechanical windrowing*, manual topping** mechanical loading into box trailers	10.2

* *by Bell loader*
** *large number of tops missed by mechanical topper due to lodged cane, removed by hand*

in faster loading of the trailers without affecting the labor requirements. Productivity was 10.2 t/man-day. This included manual topping. Unfortunately this system could not be tested in erect cane. Had this been possible, the effect of manual topping on productivity could have been established. From experience gained when using the other systems, a production of 15 t/man-day can be expected if manual topping can be avoided.

DISCUSSION AND CONCLUSIONS

The harvesting systems discussed here are based on simple cane cutters which they provide a wide choice to growers who might be forced to reduce their labor requirements. All these systems are compatible with existing manual or semi-mechanized wholestalk harvesting operations and the extent of mechanization can be left to the discretion of the grower.

Starting from the conventional system of cutting and stacking manually, a grower can mechanize by degrees, initialy incorporating only a mechanical cutter. The transportation system does not need to be altered and productivity could be raised from 4.5 to 7.5 t/man-day (67%). If the availability of labor decreases further, the acquisition of a Bell type loader for mechanical stacking could be introduced to increase labor productivity to 14.9 t/man-day, while still retaining self-loading trailers.

The use of a mechanical cutter may increase labor productivity from 6 to 10 t/man-day (67%) for growers who cut and windrow the crop manually. This would not require a change of existing loaders and box trailers. For improvement on this system, a Bell type loader would be necessary for productivity to increase to 15 t/man-day.

The total harvesting cost per ton of sugarcane will depend on the tonnage harvested annually. For growers cutting less than 50 t/day, manual cutting and stacking (at 4.5 t/man-day) is still the cheapest harvesting system in South Africa today. If the cost of this system when harvesting 50 t/day is assumed to be 100 cents/ton, that of other alternatives would be:

(i) mechanical cutting (Sasex), manual stacking : 115 cents/ton

(ii) manual cutting and windrowing (6 t/man-day) : 133 cents/ton
mechanical loading

(iii) mechanical cutting, mechanical loading or : 142 cents/ton
stacking (Bell)

The cost of all of these semi-mechanized systems compares favorably with that of a fully mechanized chopper harvesting operation.

The South African sugar industry is presently in a favorable position. Labor willing to harvest sugarcane is plentiful and while it is available, manual harvesting should be practiced. Semi-mechanized harvesting systems, based on cutters developed by the Experiment Station, may be used to compensate for any shortfall in labor that might occur in the future.

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SISTEMAS SEMI–MECANIZADOS PARA COSECHA DE CAÑA DE AZUCAR EN UN PAIS EN DESARROLLO

A. G. de Beer

RESUMEN

Actualmente la poblacion de paises en desarrollo aumenta a un ritmo de 2.1% anualmente. Muchos de estos paises ya se estan enfrentando a un gran aumento en desempleo. El crecimiento de GDP para la mayoria de paises en desarrollo, incluyendo Africa del Sur, es muy bajo para rectificar notablemente la situacion existente de desempleo con pocas esperanza de mejoramiento para el futuro aumento en poblacion. Debemos hacer todo lo possible para aumentar las oportunidades de empleo, especialmente en las áreas rurales de estos paises.

La cosecha manual de cana de azúcar se hará menos atractiva a la clase obrera por varias razones. Por lo tanto, debe haber disponibles alternativas mecanicas para cuando la mano de obra se haga más escasa. Sin embargo estos paises en desarrollo deben esforzarse en lograr una combinación de labor y equipo apropiada para su situación en particular en vez de tratar sistemas de agricultura totalmente mecanizados.

Con este fin la Estación Experimenal de SASA ha desarrollado varias cortadoras de caña las cuales, al ser integradas a sistemas de manejo de caña apropiadas, permitiran un aumento gradual de mecanizacion. El diseño de todas estas maquinas es sencillo. Su mantenimiento y operación están muy al alcance de las habilidades de operadores de tractoras no diestros. Se ha evaluado un número de sistemas de cosecha semi-mecanizada incorporando estas cortadoras. Se puede aumentar la productividad laboral de 4.5 a 15.0 T/obrero-dia. Los costos de cosecha pueden mantenerse razonablemente bajos, y en la situación actual de Africa del Sur deben ser aun mucho más bajos que los de un sistema de cosecha totalmente mecanizado.

RECENT DEVELOPMENTS WITH THE BSPA/McCONNEL HARVESTING SYSTEM

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ABSTRACT

The paper reports the main changes made to the BSPA/McConnel machines since they were described at the XVIth ISSCT Congress. In particular, the Stage I machine has been equipped with sharpened basecutter blades and mounted on a reversed tractor. Stage II now cleans trash and tops on the bottom "fan" only with significant improvements in performance. The cane is lifted to the conveyor from the gathering sweeps of a powered roller, instead of a stationary ramp, allowing work in more wet conditions. The "Loadster" has been simplified by eliminating the telescopic extension.

Recent figures on output, cleaning and fuel used are given. A change in ownership of the project is also announced.

INTRODUCTION

The system and the equipment were described by Hudson[1] at the XVI ISSCT Congress. This paper briefly summarizes the changes it has gone through up to May, 1979. The system is now in its eighth year of development. However, because the development of this project is financed mainly from the sale of the machines, and because of the poor market conditions since the last ISSCT Congress, not as much progress has been made as was hoped for in 1977.

THE SYSTEM AS A WHOLE

It is now possible to state categorically that the Stage I and Stage II operations can result in the harvesting of wholestick, unburned cane to an acceptable X.M. level, and economic output quantity provided certain conditions are met. These conditions include the present state of the system and the following:

(a) A more-or-less flat culture
(b) Row spacings of 1.50 m or (preferably) greater
(c) Non-brittle varieties
(d) Cane not excessively tangled
(e) Row lengths of at least 150 m

If the culture is sharply furrowed or ridged, if the row spacings are too narrow, and if the variety are brittle (or excessively tangled), unacceptably high losses of cane will result due to stalk breakage. The resulting scrapping costs in these circumstances eliminate any cost benefit likely to result from the use of the complete system.

THE STAGE I REAPING AID

Sharp--tipped blades have been introduced. Even at the relatively slow tip speed of 450m/min, the fact that the blades are *ground-following* makes the sharp tip superior to the blunt blades previously used.

The use of the topper has declined in Barbados since it has been found to be cheaper to pay the labor extra for removing the tops than to deal with the problems of tractor overheating and high front axle loadings, resulting from its presence. As now used in Barbados, the reaping aid is therefore more in line with the concept employed in countries like Argentina. However, in situations where post-cutting burning can be used, a high labor output is achieved by cutting the unburned cane with topper working, and then burning the windrows on the ground. The flail-type topper works well in this context.

An important recent development has been to mount the Stage I on a tractor with reversed controls (Fig. 1). The main advantages of this are three-fold. First, that base cutting is much better in light soils (or with weakly-rooted stools). Secondly, row-following is much easier. Third, it makes the machine cheaper for lower-yielding areas which only need the base cutter unit (spiral dividers being necessary only at higher yields) and reversed tractor controls.

Although circumstances which result in appreciable cane breakage can be expected to limit the use of the complete system, the application of Stage I as a reaping aid is much wider since the retrievers are not much hindered by some cane breakage. Over 10% of the 1979 Barbados crop will be reaped via Stage I and in a very wide range of circumstances of yield, culture, topography and variety.

THE STAGE II CLEANER-PILER

Several important changes which have led to simplication and/or improved reliability have been made with this unit.

The most significant change is that, following work by the SASEX engineers, all the trash and tops are now removed from the bottom "fan" only. This is achieved by a modest downward airflow just rearwards of the "hurler" unit to ensure that

trash and green leaves move away from the top hurler roller. The air -flow is effected at present by simply rotating the shroud around the top fan by about 180° (Fig. 2). This change has resulted in better cleaning and in the elimination of the "sweep" or "carousel" unit (shown in the 1977 paper). The change also allowed for all trash to be deposited neatly under the machine. The shroud shape to achieve adequate air movement off the top "fan" is quite critical and future developments will, probably follow the SASEX use of an axial or centrifugal fan.

The second major change is the replacement of the stationary ramp behind the gatherer sweeps by a powered feed roller. This enables the machine to work in very wet field conditions and is much less sensitive to bent gatherer blades in rough conditions. This feed roller has four fins of rubber belting. It is built strongly enough that if the whole weight of the machine is rested on it, a shear bolt breaks in the chain drive.

FIGURE 1. The stage 1 reaping aid with sharp base cutter blades, mounted on a reversed IH 574 tractor. This machine was christened the "Carib" Cutter in Barbados.

The friction plate clutches, protecting the gatherer drive and the hurler/conveyor drive, are now themselves protected by Bondioli and Pavesi torque limiters which incorporate a shear bolt in a standard splined yoke. It was found that users consistently failed to maintain these friction clutches correctly, and corrosion and "stiction" problems in a humid island climate made their performance erratic. By adding the shear mechanisms, the rate of breakdown has been greatly reduced.

The bin offset is now operated hydraulically from the driver's seat.

The use of a standard two-wheel drive tractor with center pivot steering

has proved very satisfactory, giving much improved row-entering characteristics.

Several components of the machine described in 1977 were found to be inadequate and have now been modified accordingly. These include the center pivot joint, the attachment of the draw-bar to the main frame, the quality of conveyor belt and fasteners, and the attachment of the bin pivot to the main frame. There have also been some minor changes to the design of the rubber cushions, and their method of attachment to the "hurler" drums.

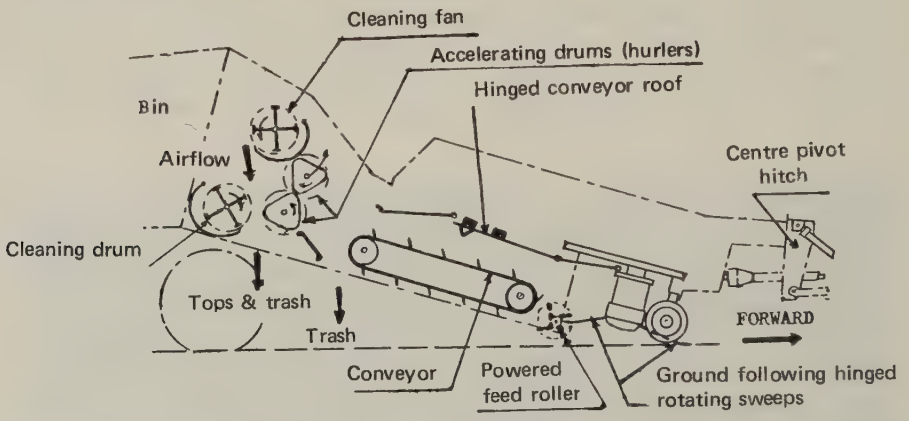

FIGURE 2. Intake and cleaning section of Stage II, showing new powered feed roller and 180° rotation of top cleaning fan shroud.

STAGE II AND BURNT CANE

Because of a severe shortage of development resources, little further work has been done on the "hybrid" machine described in the 1977 paper either in Barbados or by F.W. McConnel. However, we are encouraged by the results so far, of a major investigation being carried out by the South African Sugar Industry Experimental Station.

The two-pass approach to burnt cane is only efficient if either (a) the burn has been poor and the excellent cleaning potential of the two passes is required or (b) if the two passes are compensated by doing two rows at a time (as in the J & L two-pass approach originated by Fowler). Although high rates of work have been achieved in burnt cane with Stages I and II, the system usually leaves far too much scrapping to be done because Stage I in its present form breaks a proportion of the cane when it is not protected by trash. Two row cutting of burnt cane with a gentler action could however make the system attractive, but little work has been done so far.

"LOADSTER"

The complete system can use most types of loader common in the worlds' cane industries. The "Loadster" was developed not primarily for the loading of

cane left by Stage II, but as an answer to the needs of the following:

(a) smaller farms unable to purchase a second tractor to draw carts besides a 90° slew loader

(b) farmers worried about soil compaction (the "Loadster", towing its own carts, results in one compaction lane every 8-10 rows only)

(c) farms where the tractor carrying the loader can be used for other purposes (the Loadster is easily removed) and

(d) sloping land.

The main change in design has been the elimination of the telescopic extension of the second boom (Fig. 3) since the low reach which made this possible has proved to be not worth the extra complexity and reduced rate of work.

FIGURE 3. The 2-arm version of the Loadster working on a small farm in Barbados.

TRACTORS

The basic philosophy of attaching the equipment to standard agricultural tractors is proving to be a good one. More emphasis will now be placed on making the attachment/detachment even easier and quicker.

TABLE 1. Outputs of Stage II and fuel use for the complete system in green cane

Country	Circumstance	Output of Stage II – tons per tractor hour including travel to and from field	Fuel use for Stage I, Stage II and Loader. Liters per ton onto road transport including travel
Barbados	Yields ranging from 20-100 tons per hectare. 5 machines 1979 crop.	machine A 10.9 machine B 10.0 machine C 9.4 machine D 7.6 machine E 7.5	1.10 (1978): 1.26 1.40 (1979) 1.35 1.72 2.30
N.E. Brazil	Unmodified 1977 models of both Stage I and Stage II	6½–21¾ (11¾ overall)	c 1.5
Costa Rica	La Hilda Estate, unmodified Stage II	8(in 1977)	1.9
S. Africa	Assessment by SASEX various trials with 1977 and 1978 models	10 – 20	1.3
Mauritius	Various trials with 1978 models	18 – 22	between c 1.2 and 2.3

OUTPUTS

The ceiling hourly outputs are still more or less as quoted at the previous Congress. All the machine in Barbados are limited by either quota or labor availability and judgements on output are not easy. "Real life" outputs, within the context of these limitations (and inadequate field conditions generally) are listed in Table I. Some ideas of the possible Stage II output may be gained from the fact that Stage II "A" is now in its second year of operation and is achieving a weekly average of approximately 80% of two combine harvesters working on contract in similar circumstances.

FUEL USE

Although the fuel cost per ton is not a high proportion of total costs, it has important long-term implications, including its value in assessing the general wear and tear on machinery since fuel consumed means power to be disposed of, and power disposal implies punishment of all moving parts. Table I gives figures collected so far. A typical figure for the complete systems seems to be less than 1.51 per ton loaded to road transport for *unburned* cane (Table I). Comparative figures for

TABLE 2. Extraneous matter in loads delivered by the BSPA/McConnel system (with comparison figures for other system in Barbados)

Country	Circumstance	% Tops	% Trash	% Stumps soil etc.	Total % X M
Barbados (1979 crop to 11th April) (brackets show number of loads sampled	Hand cut, hand load (1,019)	1.61	2.34	0.01	3.96
	Hand cut, machine (733)	1.37	2.96	0.44	4.77
	Stage I + hand-pile + machine load (137)	1.17	2.94	0.48	4.59
	Stage II + machine load (304)	1.91	4.02	0.54	6.47
	Combine harvester A (102)	3.85	5.85	1.05	10.75
	Combine harvester B (41)	3.90	4.50	0.52	8.92
	Combine harvester C (82)	3.51	3.10	0.88	7.49
N.E. Brazil	Pile sampling (1977)				4½–5½
	Factory samples (1979)				c. 10
Costa Rica	Data for 1977 only				2.6
S. Africa	Various measurements				3 – 5
Mauritius	Pile sampling and Factory sampling				3½–8

combine harvesters in Barbados in 1979 were between 1.61/ton and 2.91/ton depending on the machine and the farm. Considering that four tractors (Stage I, Stage II, Loader and accompanying haulage tractor) are involved, as compared with only three power units for the combine machines (harvester and two in-field tractors), this result has surprised many people. The main reason for the lower fuel consumption/ton are probably as follows: the Stage II cleaning mechanism is far less power-consuming than fans; no power is used for chopping the cane; the ground-following base-cutting blades can be less power-consuming than rigid discs when these bottom goes into the soil in non-ideal row preparation.

EXTRANEOUS MATTER

Properly used and with suitable varieties and land preparation, the Stage I operation plus manual retrieval and mechanical loading should deliver cane to the factory at less than 4% total XM; while the complete system should be less than 5%. These figures have been made better frequently in Barbados, but many conditions are still far from ideal. Table 2 summarizes the factory sampling in Barbados for most of the 1979 crop, plus a few reported figures from other countries.

A typical figure of less than 6½% is currently being achieved and further improvements are possible.

CHANGE IN MANAGEMENT OF THE PROJECT

This opportunity is taken to record appreciation for the way the Directors of F.W. McConnel took up the Barbados ideas and developed them in the face of great difficulties. The slump in cane machinery sales during the last few years was detrimental to such a development and although the exercise was profitable for the sub-contractors and the Barbados Sugar Producers' Association, it was not so for McConnels. The project will now continue directly through the Barbados Sugar Producers' Association, will manufacture by the same sub-contractors who make the machines at present, and via licensing agreements with Industries wishing to make their own units. "Challenger" Ltd. will make and distribute the Loadster.

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EVOLUCIONES RECIENTES DEL BSPA/SISTEMA DE COSECHA McCONNEL

D. A. Scott y J. C. Hudson

RESUMEN

Este artículo trata sobre las modificaciones principales hechas a las máquinas McConnel BSPA desde el XVI Congreso de ISSCT. En párticular la maquina STAGE I ha sido equipada con cuchillas de base y montada en un tractor revertido. STAGE II ahora limpia la basura y el cogollo con el "abanico" inferior unicamente, con mejoras significativas en su funcionamiento. Un rolo motorizado, en vez de una rampa estacionaria, levanta la caña apilada hasta el conductor, permitiendo asi trabajar bajo condiciones mas humedas. El "Loadster" ha sido simplificado por la eliminación de la extensión telescopica.

Se presentan obras recientes de producción total, limpieza y consumo de combustible. Se anuncia un cambio de propiedad del proyecto.

THE PERFORMANCE OF CHOPPER HARVESTERS

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ABSTRACT

A review is given on the performance of chopper harvesters in various countries. Test procedures for sugarcane harvesters are considered by describing an experiment conducted during 1978 on an estate in Swaziland to determine the losses of a sugarcane crop incurred when harvesting mechanically with two different machines, in comparison with those incurred when harvesting conventionally by had and transporting the cane on selfloading trailers. Of the estimated 118.9 tons cane per hectare standing in the field, it was determined that 116.4 tons/ha were recovered when hand harvesting, 110.8 tons/ha when using machine A, and 100.7 tons/ha when using machine B. Because the cane had been treated with a chemical ripener and an excellent burn was obtained, the amounts of extraneous matter tended to be low in all treatments. For hand cutting they were 3.1%; for machine A, 6.1%; and for machine B, 7.0%. Compared to hand harvesting, the use of machines A and B resulted in sucrose losses of 4.5% and 12.5%, respectively.

INTRODUCTION

Much more is known today about chopper harvester performance than was known ten years ago. Field personnel and researchers from various countries have reported on factors such as machine efficiency, quality of the sample, the effect of extraneous matter on mill output and sugar recovery, and on total field losses incurred by using these machines. A brief of some of the above findings is presented in this paper. Test procedures for chopper harvesters is discussed by describing a recent trial conducted by the S.A.S.A. Experiment Station on two harvesters in Swaziland. Current work in Australia (Foster *et al*[10], Fuelling *et al*[11] Mason *et al*[16]) where in-depth studies are being conducted on factors such as the effect of harvesting rates on billet quality and machine performance, will not be dwelt on, as these aspects will be covered fully in two other ISSCT papers titled "Review of cane harvester performance" by V. Mason *et al* and "Recent studies on cane deterioration in Australia" by D.H. Foster, *et al.*

First reports on machine output received from countries other than Australia,

presented a very poor picture. It was, however, soon appreciated that properly prepared fields were essential if acceptable performances were to be obtained from these machines. Papers published in Jamaica (Siriisa[23]) and Mauritius (Hoaran and dela Giroday[14]) indicated that field efficiences of about 40% could be expected. Twenty-five choppers in the French West Indies (Dutarte[7]) gave an average field efficiency of 45%. In South Africa (de Beer and Boevey[6]) it was established that while actual pour rates were 60 t/h or more, productivity averaged only 20 t/field hour. Even under ideal conditions, 10% of the total field time was lost when turning in the headlands. Of course, factors such as field layout and availability of infield cane transport will affect field efficiency. Under good field and management conditions, as they obtain in Australia, field efficiency. Under good field and management conditions, as they obtain in Australia, field efficiency can be as high as 60% (S.W. Boxter, personnel communication). Harvesting green cane in Texas in 1977 with eight different harvesters resulted in a reduction of 68% in pour rate compared to that for burnt cane at 66 t/h (Rio Valley Sugar Growers[17]).

Increased amounts of extraneous matter will adversely affect haulage payloads, mill throughput and sugar recovery. Clayton and Whittemore[1] reported that each one percent of trash content resulted in a loss of 1.5% to 2.0% in the value of the sugar produced. South African tests (Scott[19]) at two mills showed that extraneous matter decreased the crushing rate by 2.2 to 3.0% for every addtitional 1% of trash (leaves) % cane. Tops did not adversely influence the rate of cane throughput. The effect of trash on sucrose % cane is illustrated by the fact that if clean cane contains 13% sucrose, additions of 5, 10 and 20% trash will reduce this value to 12.35, 11.70 and 10.40%, respectively. This effect is further illustrated by the analysis of extraneous matter given Table 1. (Scott[20]). Data for this Table were obtained in a laboratory investigation, and it was concluded that both tops and leaves had pronounced adverse effects on juice purities and clear juice quality. In addition, trash (leaves) aslo reduces pol extraction. All these effects were found to increase linearly with extraneous matter contents up to 30%.

Various studies (Clayton *et al*[2], Cruz[4], EEA[8], Fernandez *et al*[9], Humbert[15], Tambosco *et al*[24]) have shown extraneous matter contents of chopper-harvested cane to vary from 6 to 17%, compared to those of handharvested cane of 3 to 7%. Compared to manual cutting and push-pole loading, chopper harvesters do, however, substantially reduce the quantity of soil delivered with the cane (Smith[21]). In Brazil a reduction in mineral matter of three times to 0.8%, was recorded in one study (Fernandez *et al*[9]) while in another (Tambosco *et al*[24]) soil content ranged from 0.1 to 0.3% for chopped cane as compared to 0.5 to 3.1% for mechanically-loaded cane.

The Bureau of Sugar Experiment Stations, Australia, had developed a convenient method to sample the cane delivered by a chopper harvester (Fueling *et al*[11]).

A portable light-weight chute is attached to the back of the haulout bin or trailer. Samples are taken by signalling the haulout driver to move forward briefIly so that the harvester discharges directly into the chute. A bag attached to the bottom of the chute then catches the sample. This sample is likely to be quite representative.

Field losses of sugarcane due to chopper harvesting consist of cane left behind in the field and losses of juice and cane fragments so small that they cannot be gleaned (invisible losses). Cane left behind can be easily determined by careful gleaning of marked-off plots immediately following harvesting. Typical values for this part of the cane loss vary from 2 to 10% (de Beer and Boevey[5], Mason *et al*[16] Smith[21], Zepp and Clayton[26]).

Invisible losses are more difficult to determine, especially under actual operating conditions. A survey of invisible losses was made when using six chopper harvesters in Florida in 1974 (Joe E. Clayton, personal communication). This followed on reports from Australia (Vallance[25]) that losses were 19% and up to 30% when pre-weighed cane was fed through harvesters. In the Florida study, harvesting mechanisms and extractor fans were operated at normal speeds and pre-weighed cane was fed thorugh the machines. After the test, all cane found inside the machine was added to that which dropped out of the harvester. There was still a shortfall of 3.2%, which was regarded as an invisible loss, probably due to the disintegration of billets and lost juice. According to a Mexican study carried out in 1975 (CNIA[3]) two chopper harvesters delivered 78% of available millable cane as compared to 94% from manual cutters. Both "cane left behind" and "invisible losses" were probably included in these figures.

A 1976 study at Rio Grande Valley Sugar Growers, (Rozeff and Tucker[18]) comparing hand cutting with a chopper harvester, indicated that little, if any, juice was lost in the mechanical harvesting operation. However, when testing eight different models of chopper harvesters in 1977 (RGVSG[17]) in a field averaging 133 t/ha, it was found that 15% of the pol available after burning was lost during the harvesting operation. This loss was made up of 1% pol recovered with the trash, 10% lost in scrap left behind in the field and 4% on undetermined or invisible loss. These values were determined by comparing the pol % cane and fiber, of hand cut samples and the net cane component of the gross cane delivered by the machines.

During 1976 it was reported in Hawaii (Gibson *et al*[12]) that the extraction fans of a specially-built chopper harvester removed 2.0 tons recoverable pol/ha from 261 tons of sugarcane/ha. South African test (de Beer and Boevey[5],-SASAES[22]) based on direct comparisons of millable cane delivered by machine or following manual cutting, gave invisible losses due to chopper harvesting of 4 to 15%. The lower values were found with well-maintained machines, while the higher values were for machines obviously in need of attention.

In the final analysis, machine efficiency, trash content, sample quality and

cane losses will be determined not only by the machine and its inherent design, (Hackett[13]) but also by factors such as cane variety, burn quality, moisture content of the soil, base cutting height, topper height setting, blade sharpness, production rate and erectness of the cane.

During 1978 the Experiment Station of the South African Sugar Association had the opportunity to compare two makes of chopper harvesters with hand cutting. This enable the Experiment Station to further evaluate test procedures for these machines, one of the objectives set by the ISSCT Standing Committee on Mechanical Harvesting and Cane Quality.

The 1978 tests were performed at Mhlume Sugar Company, Swaziland, on two makes of sugarcane chopper harvesters. The aim of the tests was to observe the field losses incurred when each of the machines was used, in comparison with those incurred when the normal standard of hand cutting was practiced by Mhlume Sugar Company.

TEST PARTICULARS

The rest was done on 39 sprinkle lateral blocks, with an average size of 0.37 ha, on the Ematsheni Section from 7 to 11 August 1978. The three treatments, Chopper A. Chopper B and hand-cut, were randomly assigned to each group of three lateral blocks, with thirteen replications per treatment.

The whole field was burned at one time and harvesting commenced with five replications being hand-cut on August 7. This cane was hand-stacked for self-loading trailers to deliver the bundles to a transloading zone for further transport by road vehicle to the mill. Hand-cut cane was crushed on the day following cutting. Five additional replications were cut on August 8 and 9, respectively.

Both chopper harvesters were practically new, having only been used for demonstration purposes before the tests. Machine A was in excellent condition, being under the supervision of and being maintained and adjusted by the manufacturer's representative. Machine B did not receive the same attention, being operated without the agent's presence. Two local chopper harvester operators, used to another make of machine, operated the harvesters but both had adequate practice on the two machines in question before the test began.

The chopper harvesters started cutting on August 8, with the cane delivered directly from the field to the mill in 10-ton containers. Chopper-harvested cane was crushed within two hours of cutting. Only one machine operated at any particular time, allowing about 40 tons from each lateral to accumulate on the mill carrier for continuous crushing. Four replications were cut by each machine on the 8th, seven by machine A and one by machine B on the 9th, and the last two were harvested by machine A on August 10.

It soon became obvious that machine B was performing very badly and eratically. This was apparently due to a lack of proper setting and maintenance. This harvester was therefore withdrawn from the test after cutting only five replications.

Choppers A and B cut at average rates of 40.5 and 27.1 tons per field hour, respectively. The cane was a fourth ratoon NCo 376 which was 12.7 months old. Because a cane ripener had been used, the quality of the burn was exellent. Recumbancy was judged to be 25% occurring in patches in the field. Field conditions were dry, and the average daily maximum and minimum temperatures were 28°C and 13°C, respectively. Average relative humidities at 08h00 and 14h00 were 83 and 31%, respectively. The cane rows were 216 m long, spaced 1.5 m apart, with the cane grown on a ridge of about 100 mm. Each lateral block consisted of 11 cane rows, yielding about 44 tons each. Average yield for the field was 109.1 tons/hectare at 14.24% sucrose.

EXPERIMENTAL PROCEDURES

To be relevant, the tests had to be done under infield harvesting conditions, but they could not be allowed to disrupt normal harvesting schedules to a significant extent. It was also realized that the testing procedures should not require unrealistic resources as far as manpower, testing equipment and time were concerned.

Cane sample

The first factor considered in determining field losses was the amount of extraneous matter delivered to the mill with the harvested cane.

Hand-harvested cane was placed in windrows, stacked manually and the stacks were then picked up by self-loading trailers. Eleven random samples of 15 to 25 kg were taken to represent each treatment block from the windrowed cane before it was stacked. Samples were taken by removing stalks from all levels of the windrow to ensure that cane from all the rows included in that windrow were represented. The samples of stalks were weighed as they were taken from the windrow. All tops and other trash still adhering to the stalks were then carefully removed and the cleaned stalks were weighed again. This gave a measure of the extraneous matter content, which was then expressed as a percentage of the total sample. Extraneous matter is defined as all materials other than millable cane. With this handling method, it was not possible that the commercial cane could be contaminated by additional extraneous matter (such as soil) subsequent to sampling.

Samples from chopper-harvested cane were taken directly from the machines. On a signal, the harvester operator stopped the elevator and the harvester, and the bin trailer was moved slightly forward to be out of the way. A canvass sheet was then held in position below the elevator and the operator started the elevator again.

Between 15 and 25 kg of cane were caught on the sheet. During this operation all fans were kept going at normal operating speeds. The canvas sheet was large enough to catch all cane and extraneous matter delivered from the elevator. Care was taken, however, to ensure that trash did not get blown away. The machine then caught up with the trailer and continued to harvest normally. This procedure resulted in a minimum of delay to the harvester. Each sample was immediately analyzed for cane and extraneous matter, the latter again being expressed as a percentage of the total. One sample was taken at random per row or cane in each test block, resulting in eleven samples per treatment block.

Net cane delivered

The quality of net cane delivered at the mill was found by subracting the estimated amount of extraneous matter determined by means of the cane sample hired from the gross mass of cane as determined on the weighbridge.

Gleaning after harvest

Handcut blocks were gleaned by the team of laborers normally hired for this task. Gleaned cane was weighed in the field by a tractor-mounted grab fitted with a load cell. No gleaning of machine-cut cane occurred after harvest, but two field laborers worked with each chopper harvester and placed come left-over cane in the next row to be cut. These gleaning procedures correspond to those normally used by Mhlume Sugar Company.

Cane left in field

After all harvesting operations had been completed in each lateral, three random sample plots were marked out per lateral by means of pegs and strings. These plots were 3 m square, i.e. 9 m^2 each. All "millable" cane inside the demarcated sample plots was gathered and the weight determined. Millable cane consisted of all pieces of cane recognizable as such. Where topping was too low, that part of the top regarded as "millable cane" was broken off at the natural breaking point. Where base-cutting was obviously too high, the stubble was cut by hand. Any piece of millable cane lying across the plot demarcation line was cut at the line and the part left on the inside was collected. The millable cane collected from each sample plot was expressed in terms of tons per hectare. In the case of chopper-harvested cane, care was taken to ensure that sample plots were marked out only on that part of the field traversed by both the harvester and the bin-carrying trailer.

Mill analysis

Approximately 40 tons of sugarcane were cut from each treatment block and delivered in one batch to the mill. This quantity of cane was adequate for mill sampling for sucrose and purity determinations.

Billet quality

Seven samples for machine A and six for machine B, each approxinately 20 kg. were taken from the cane delivered by the chopper elevator and analyzed for extraneous matter content and billet quality based on procedures developed by Australian researchers. (Foster *et al*[10], Fuelling *et al*[11], Mason *et al.*[16])

TABLE 1. Typical analysis of clean cane and extraneous matter

	Brix %	Pol %	Apparent Purity	Fiber %	Moisture %	Non-pol %
Clean cane	16.7	14.8	89	12.8	70.5	1.9
Tops	6.7	1.4	21	16.6	77.7	5.3
Trash (leaves)	7.8	1.5	19	58.6	33.6	6.3

RESULTS AND DISCUSSION

The results of the tests are summarized in Table 2.

TABLE 2. Summary of results

	Hand	Chopper A	Chopper B
Gross cane delivered (t/ha)	120.10	117.94	108.36
Extraneous matter (%)	3.10	6.05	7.00
Net cane delivered (t/ha) (including gleaning)	116.37	110.78	100.66
Left behind in field (t/ha)	2.53	3.04	6.08
Loss vs total millable cane (118,90t/ha) (%)	2.13	6.83	15.34
Loss vs hand-cut + gleaning (%)	–	4.80**	13.50*
Sucrose % cane	14.35	13.95*	13.95*
Purity %	88.48	87.35**	87.54**
Sucrose (t/ha)	17.22	16.44*	15.07*
Loss in sucrose vs hand-cut + gleaning (%)	–	4.50	12.50

* *Difference from the hand-cut treatment is significant at 5% level.*
** *Difference from the hand-cut treatment is significant at 2% level.*

Total millable cane

A measure of the total tons of millable cane on the field before harvest can be found by subtracting the extraneous matter from the hand-cut cane delivered to the mill, then adding what was gleaned and what was found to be left behind. The average for the 13 replications was 118.9 t/ha.

Net cane harvested

The amount of net cane normally harvested by Mhulme, when hand cutting is practised, can be estimated as the total millable cane less that portion left behind in the field after gleaning i.e. 116.4 t/ha. For the chopper harvesters it would be the gross tons cane delivered at the mill less the extraneous matter. This was calculated to be 110.8 and 100.7 t/ha for machines A and B, respectively.

Gleaning after harvest

By gleaning the hand-cut blocks, 0.9 t/ha of cane was retrieved. Gleaning of chopper harvested blocks was not deemed to be worthwhile.

Cane left in the field

Even after gleaning, 2.5 t of cane per ha was still left behind in hand-cut blocks. Chopper A and chopper B left behind 3.0 and 6.1 t/ha, respectively. Chopper A was clearly harvesting more cleanly and its base cutting was lower than that of chopper B.

Mill analyses

Sucrose % cane was 14.35, 13.95 for cane cut by hand, by machine A and by machine B, with juice purities of 88.5, 87.4 and 87.5, respectively.

Billet quality and extraneous matter

The low extraneous matter content of both hand-cut (3.1%) and chopper-cut cane (6.1% for A, 7.0% for B) must be ascribed to the excellent burn resulting from the prior use of chemical ripeners and the dryness of the weather.

Table 3 provides further evidence that machine A was cutting lower than machine B. This resulted in higher dirt and root percentages for machine A, but for both machines these values were negligibly small. Billet quality did not differ much between the two machines but machine A did show a marked improvement in sound cane (64.8%) after sharpening of blades. The lengths of the billets differed considerably, with machine A delivering shorter billets of more consistent length than those delivered by machine B (Fig. 1). In the case of Mhlume Sugar Company,

the amounts of damaged and mutilated billets are probably not important because chopped cane is usually crushed with two hours of cutting.

Field losses

Of the total amount of millable cane (118.9 t/ha), hand cutting resulted in a loss of 2.13%, chopper A caused a loss of 6.83% and chopper B a loss of 15.34%.

Compared to hand cutting with gleaning, as normally practiced by Mhlume, mechanical harvesting resulted in a millable cane loss of 4.80% and 13.50% for choppers A and B, respectively. Mechanical harvesting resulted in a loss in sucrose of 4.50% and 12.50% for choppers A and B, respectively, when compared with hand-cutting as practiced at Mhlume. Juice purities were also significantly lower when mechanical harvesting was practised.

The results obtained with chopper A, taking into account its high cutting rate. are nevertheless as good as those found previously by the Experiment Station for other machines. The results obtained using this machine are indicative of what can be expected with a chopper harvester when it is in good repair and with proper settings and maintenance.

The poor results obtained with chopper B should not be taken as typical for tha make of harvester, but should rather serve as a warning of the deterioration in performance to be expected when a machine is neglected.

CONCLUSIONS

Considering the results of the 1978 Swaziland tests as well as those reviewed in the introduction to this paper, the performance of chopper harvesters can be summarized as follows:

1. Field efficiency will be about 40% under field conditions which are normally to be found in most countries. Under excellent field conditions, the efficiency could increase to 60%.

2. The harvesting rate can exceed 60 t per operating hour (pour rate), but in practice this will usually decrease to 10 to 30 t per field hour. In green cane, the pour rate of existing harvesters will be reduced to 20 to 30 t per hour.

3. Chopper harvesting will result in increased amounts of tops and leaves in the sample. The amount of extraneous will be affected by field conditions but will generally be 6% under good field conditions and up to 17% under poor conditions. Increased extraneous matter contents will have a detrimental effect on mill performance and sugar produced, in direct proportion to the amount of extraneous matter in the sample.

4. Chopper harvesters, compared to mechanical loading, will substantially reduce the amount of soil delivered with the cane. Soil % cane can be expected to be less than 0.3%.

5. Chopper harvesting will lead to a loss of millable cane. For well maintained machines these losses will be in the order of:

Cane left behind in the field : 2 to 10%

Invisible losses : 3 to 6%

TABLE 3. Sample analysis and billet quality

Sample No.	Tons* cut	Sample size (kg)	Roots %	Dirt %	Tops %	Trash %	BILLETS Damaged %	BILLETS Mutilated %	BILLETS Sound %
MACHINE A									
1	20	12.78	0.1	0.1	2.6	0.2	21.0	24.1	51.9
2	40	16.85	0.3	0.2	2.9	–	30.3	21.6	44.8
3	140	17.28	–	0.1	3.5	–	25.9	26.3	44.3
4	160	19.74	2.2	0.2	5,2	–	29.3	23.2	42.1
5	10	14.85	2.2	0.6	3.6	–	10.0	18.9	64.8
6	160	17.74	–	0.2	3.0	–	19.7	23.3	53.9
7	250	21.41	–	0.5	3.5	–	14.4	32.4	49.2
		Av.	0.4	0.3	3.5	–	21.5	24.3	50.1
MACHINE B									
1	20	24.98	0.1	0.1	3.4	0.5	22.3	30.6	42.0
2	40	16.57	0.1	0.1	3.9	–	26.3	36.0	33.6
3	125	27.66	–	0.1	3.0	–	30.4	18.7	47.8
4	150	24.82	–	0.1	4.4	–	26.7	19.4	49.5
5	155	24.18	–	0.1	3.4	–	25.4	26.3	44.8
6	194	17.94	–	–	4.3	–	18.3	22.6	54.7
		Av	–	0.1	3.7	0.1	24.9	25.6	45.4

* *The number of tons cut after setting of machine, sharpening blades, etc.*

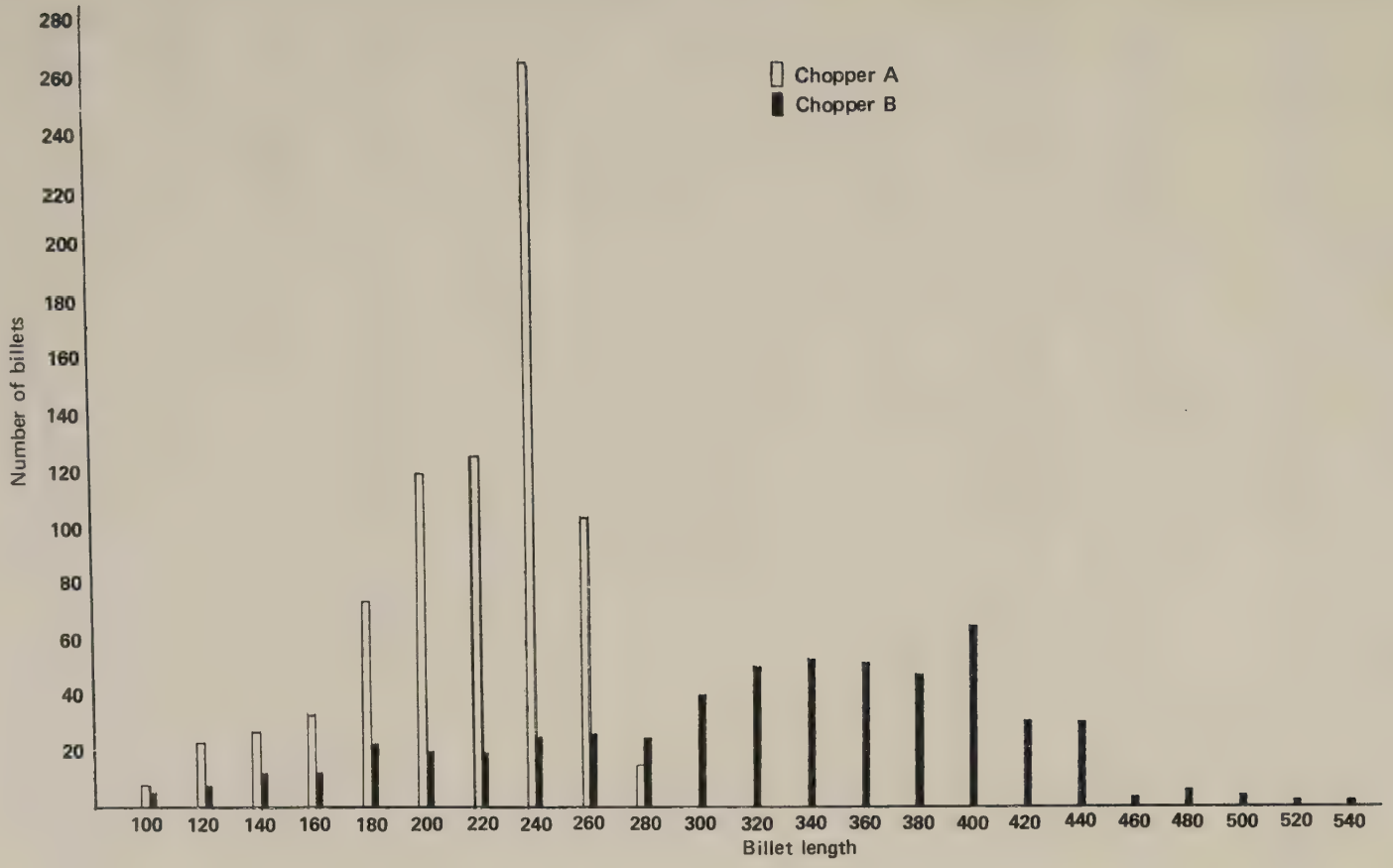

FIGURE 1. Distribution of billet lengths

For neglected machines, these losses will be much higher.

One aspect on which very little data has been published is the cost of chopper harvesting. Life expectancies of mechanical harvesters under defined conditions are also unknown.

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RENDIMIENTO DE COSECHADORAS TROZADORAS

A. G. de Beer

RESUMEN

A continuacion damos una reseña de los resultados obtenidos en varios paises con el uso de cosechadoras trozadoras. Los procedimientos de pruebas para cosechadoras de caña se consederan mediante la descripción de un experimento llevado a cabo en 1978 en una hacienda en Swazilandia con el fin de determinar las perdidas durante una cosecha de caña al usar dos cosechadoras distintas, en comparación con las perdidas cuando la cosecha se llevo a cabo por el medio convencional de mano de obra y la caña fue transportada en carretas autocargables. De un estimado de 118.9 toneladas de caña por hectarea en un campo, se determino que 116.4 tons/ha fueron recobradas al usar mano de obra, 110.8 tons/ha usando la maquina A y 100.7 tons/ha usando la maquina B. Como la caña habia sido tratada quimicamente para su maduracion, y la quema obtenida fue excelente, la cantidad de materia extraña fue muy poca en todos los casos. Para caña cortada a mano fue 3. 1%, la maquina A 6. 1% y la maquina B 7. 0%. Comparadas con el corte a mano, el uso de las maquinas A y B resulto en una perdida de sucrosa de 4.5% y 12.5% respectivamente.

CANE STOOL MATHEMATICAL MODEL FOR THE EVALUATION OF A TOPPER

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ABSTRACT

A sugarcane field mathematical model for predicting the results of a topper is discussed. On the basis of this model, the advantages of using the topper were established. The range of application in terms of the uniformity of the sugarcane field and cane losses was determined through a nomogram worked out during the research. The minimum allowed uniformity was 0.60 with losses up to 5%.

A nomogram was recommended in order to predict the results of the topper unit and to set the work norms of the operator.

INTRODUCTION

During the last two decades, beginning with results obtained in Australia and in other sugar producing countries, sugarcane mechanization has gained momentum. Particularly in Cuba, various combines have been introduced, such as the KTP, the Libertadora Class, the Massey-Fegusson and various prototypes have been appraised (Iglesias[4]).

Special attention has been paid to cane-top cutting elements (green stalk and green leaves) by Brito[2], as well as to the effects of various harvesting systems on raw material quality (Lage[5], Betancourt[1]).

However, the lack of a theoretical basis to correlate cane uniformity and the height of the topper in order to predict the quality of the raw material obtained and the losses produced by the system, has been a limiting factor in establishing the advantages and the limits of practical application.

In order to know the action of a topper unit, it is necessary to characterize the field in terms of uniformity and to design a cane stool model that would allow prediction of the effects of the topper unit such as the composition and losses of the processed sugarcane at various cutting heights of the machine. Thus, it would be possible to set the work norms of the combine both in quantity and

quality, to establish the limits of application of the topper and the characteristics that sugarcane varieties must have for mechanized harvesting. The symbols used are as follows:

h	length of clean cane stalks
r	length of green stalks
Θ	angle of inclination of each cane
h	cutting height of the topper
C1°	clean cane
Tv	green stalks
Hv	green leaves
Hs	dry leaves
n	numbers of stalks in each stool
u	stool uniformity
p	sugarcane losses
c	subindex indicating cut cane
nc	subindex indicating uncut cane
r	subindex indicating relative to initial value
Me	foreign matter
1	quality index equal to C1 me

THEORETICAL BASIS

Uniformity is the most important feature of a sugarcane field as far as mechanized harvesting is concerned. In the above-mentioned literature, this concept is often used in association with that of "straightness", which has a certain relationship, but is not identified. On the other hand, the concept of uniformity often refers to sugarcane of the same height, not accounting for the influence of slant.

Brito[2] introduced the concept of "height variation coefficent", taking into consideration only the stalks that are within the reach of the topper unit. He defined "straightness" as the relationship scope of the sugarcanes that are covered by the topper. Thus, a field is characterized by two factors, notwithstanding the fact that Brito finds an interdependence between them.

However, the topper covers a band that can range up to 1.6 meters. This magnitude is comparable to the distance between rows and in operation the action of the topper covers the total area of high top density to be harvested.

In order to develop the stool model, it is considered that uniformity is based on the dispersion of the projections of each sugarcane on the Y axis, in relation to the mean value of the projections, as the sole expression characterizing a field.

$$u = 1 - \frac{\sqrt{\frac{(h_i \cos \Theta_i - h\cos \Theta)^2}{n-1}}}{h\cos \Theta} \qquad (1)$$

The following describes the basis of the system of equations describing the stool. It is assumed that both the sugarcane and the green stalks have the same diameter throughout its length for all sugarcanes.

Calculation for clean cane (Cl).

Evidently:

$$h \geqslant Cl_{nc} = h_{\theta} \sec \theta \tag{2}$$

If

$$Cl_c = h - h_o \sec \theta \geqslant 0 \tag{3}$$

and

$$h_o \geqslant h\cos \theta,\ Cl_{nc} = h \text{ y } Cl_c = 0$$

$$P = \frac{h - h_o \sec \theta}{h}$$

The value 7.0 gm/cm was experimentally determined for the ratio of weight to length of both green and burned canes.

Green stalk (Tv)

Due to positive phototropism the position of the green stalk is oriented along the perpendicular field plane.

and

$$Tv_c = h\cos \theta + r - h_o \tag{5}$$

$$Tv_{nc} = h_o - h\cos \theta \tag{6}$$

If

$$h_o \leqslant h\cos \theta,\ Tv_{nc} = 0 = \text{y } Tv_c = r$$

$$h_o \geqslant h\cos \theta + r;\ Tv_{nc} = \text{y } Tv_c = 0$$

The experimental values of green cane stalk length are shown in Table 1.

In this paper r is taken to be constant:

$$r = 0.50 \text{ m}$$

A ratio of weight to length of 5.0 gm/cm was experimentally determined for both green and burned cane.

TABLE 1. Green stalk length for different varieties and stools

Variety	Stool	r (meters)
Ja 60–5	Spring left on the field	0.53
	Ratoon	0.57
	First ratoon	0.51
	Spring	0.50
My 55–14	Spring left on the field	0.49
	Ratoon	0.47
	First ratoon	0.54
B 43–62	Ratoon	0.45
	Winter	0.58
	Spring	0.56
C 87–51	Ratoon	0.53
	First ratoon	0.57
CP 52–43	Ratoon	0.44
	First ratoon	0.52
	Winter	0.46

$$F = 0.51 \pm 0.04$$

Green leaves (Hv)

In practice, there is a direct relation between the quantities of Hv and Tv, thus it is assumed that:

$$Hv = K\ Tv \qquad \text{where, } K = \text{Proportionality factor} \tag{7}$$

The values of leaf and green stalk content reported in the literature as well as those experimentally obtained are shown in Table 2.

Dry leaves or cane trash (Hs)

A relation between dry leaf weight and stalk length is to be expected both in green and burned sugarcane, despite the fact that in the latter case the absolute value of dry leaf weight will be small.

Thus:

$$Hs = K\ Cl \qquad K = \text{Proportionality factor} \tag{8}$$

TABLE 2. Values of leaf and green stalk content at the sugarcane tops

Variety	Stool	According to Lodos and Casanova		According to Brito 2	
		Tv%	Hv%	Tv%	Rv%
Ja 60–5	PQ	58	42	47	53
	Ratoon	58	42		
	First Ratoon	56	44	47	53
	Spring	60	40		
B 4362	Ratoon	61	39	47	53
	Winter	53	47		
	Spring	59	41	44	58
C 8751	Ratoon	57	42	39	61
	First Ratoon	57	43	37	63
Average	Tv = 51%		Hv = 49%		

Experimental values ranged from 0.68 to 1.34 gm trash/cm cane for green cane and from 0.05 to 0.10 for burned cane.

In this paper, $K = 1$ that is,

$$Hv = Tv$$

In this paper $K = 1.00$ for green cane and $K = 0.10$ for burned cane.

"Stool" system of stalk

From the expressions (1) to (8), the equations defining the stool are obtained and shown in Table 3.

RESULTS AND DISCUSSION

Experimental determinations of the various parameters describing the vegetative structure of the sugarcane plants and uniformity of various sugarcane fields were determined experimentally.

A program for the CID-201 B computer, capable of obtaining the composi-

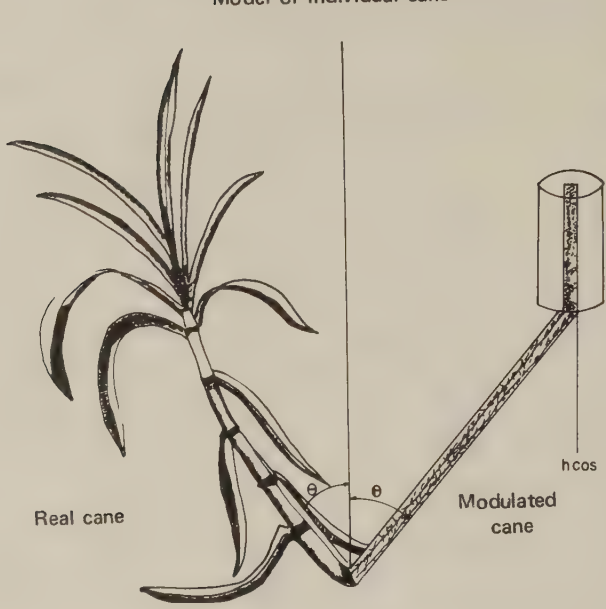

FIGURE 1. Actual cane and its model according to the equation system.

TABLE 3. Expressions for calculating the components of a cane stool

Vegetative	Component	Cut (c)	Uncut (nc)
Σh_i	Cl	$\Sigma (h_i - h_o \sec \theta_i)$	$\Sigma h_o \sec \theta_i$
nr	Tv = Hv	$\Sigma (h_i \cos \theta_i + r - h_o)$	$\Sigma (h_o - h_i \cos \theta_i)$
$K \Sigma h_i$	Hs	$K \Sigma Clc$	$K \Sigma Cl_{nc}$

$$P = \frac{\Sigma (h_i - h_o \sec \theta_i)}{\Sigma h_i}$$

$$V = 1 - \frac{\sqrt{\frac{\Sigma (h_i - \text{Cos } \theta_i - h \text{ Cos } \theta)^2}{n-1}}}{n \text{ Cos } \theta}$$

tion and losses at various heights of the topper was designed.

There are certain distribution of cane that result in two stools having the same uniformity with different heights. This made the analysis difficult. Therefore, in all cases the equations of the model were worked out with heights, hr related to mean height both of canes and green stalks.

The relationships between cane losses and cane height for different height uniformities are shown in Fig 2.

The family of lines for uniformity indicates that for U values lower than 0.6, cutting heights became very high implying a slight increase in the quality index of the sugarcane.

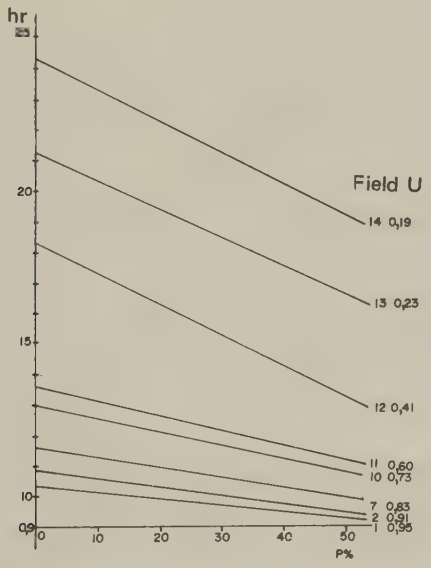

FIGURE 2. Cane losses according to relative cutting height, for different height uniformities

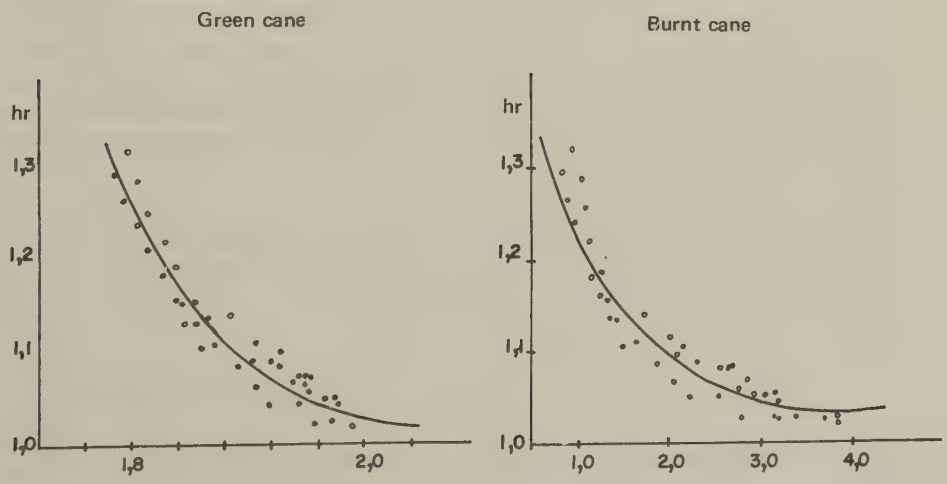

FIGURE 3. Relative increase in quality index Ir according to relative cutting height

The expression obtained for the family of straight lines under the study was:

$$h_r = \frac{h_o}{h} = (2.105 - 1.1261\ U) + (0.0956\ U - 0.1114)\ P \quad \text{for } U > 0.6 \tag{9}$$

From this expression, the dependence of h_r on U for different losses may be established.

The relation between the quality index and cutting height was also obtained. In this case, too, the index obtained was referred to the initial index in order to eliminate differences between stools. Fig. 3 shows the relative increase in quality index Ir according to relative cutting height hr.

The results were processed according to a potential program, obtaining.

Green Cane

$$h_r = 2{,}322 - 1{,}7171_r + 0{,}780\ I_r^2 - 0{,}122\ I_r^3 \tag{10}$$

Burned cane

$$h_r = 1{,}510 - 0{,}361\ I_r + 0{,}088\ I_r^2 - 0{,}007\ I_r^3 \tag{10}$$

With a correlation coefficient of 0.97 is in the range under consideration.

These expressions were independent of U.

It is obvious that a grower, when investing in the addition of a topper to a combine, wishes to improve the quality of his sugar cane with the least possible loss. That is to say, he wants that the increase in cane quality and the mill profits to surpass the loss. By combining the expressions 9 and 10 Fig 4 was obtained, in which it can be seen that in a field of U = 0.6 the use of topper does not satisfactorily increase cane quality since losses are up to 5%. The quality of the cane may decrease if smaller losses are forced.

Lodos[5] reached the conclusion that the expression correlating the efficiency of a cleaning system with the recovery, taking into account the increase in sugar loss in bagasse due to an increase in foreign matter, was:

$$K = \frac{fB}{100\ P\text{-}FB} \tag{11}$$

		Values
f	fiber in Me	25
F	fiber in cane	14
B	loss in bagasse	6
P	sugar content in cane	14

On the other hand, the relation established by Buchanan[6] allowed us to assume that loss in molasses resulting from the presence of non-sugars in the cane-top were at least as great as the loss in bagasse.

By evaluating expression 11, we concluded that it was necessary to eliminate approximately four times the amount of foreign matter compared to the amount of cane in order to compensate for sucrose loss in bagasse and in molasses.

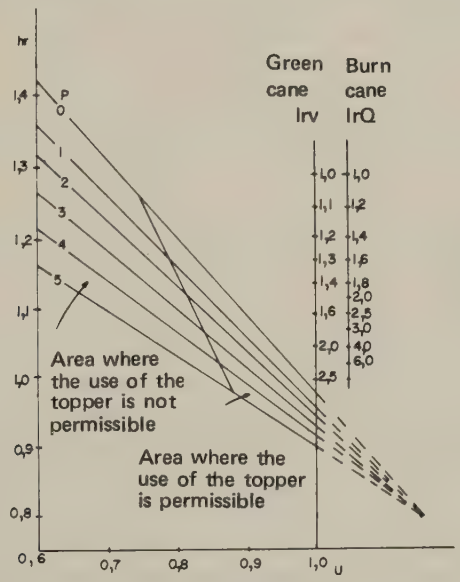
Ir
P
Green cane Irv
Burn cane IrQ
Area where the use of the topper is not permissible
Area where the use of the topper is permissible
U

FIGURE 4. Relationship among cutting height uniformity v, cane losses P and quality Ir obtained from the raw material following the utilization of a topper.

This did not take into consideration the additional effects of foreign matter on equipment wear, capacity loss, increase of mud, and clarification difficulties which may be very significant.

Fig. 4 represents the nomogram that relates cutting height to field uniformity, and allows us to forecast losses in sugar cane and the quality increase obtained by the action of the topper.

The shaded area comprises the range where the use of the topper is justified. This area is covered by the following values $0.90 < h_{lm} < 1{,}25$ y $U > 0.75$.

It must be pointed out that the operator of the combine can improve the results given by the topping unit which supposes a constant height. In fact, the operator raises or lowers the topper according to his appraisal of each stool and to

his skill. The effect of the topper will be greater in proportion to the fraction of stools which have a U greater than 0.75.

Brito[2] working with an individual topper in a row of stools determined U and P experimentally. The data provided by him allows us to calculate Ir. Table 4 shows the results of the Ir's predicted with the model discussed in this paper.

TABLE 4. Experimental values of U, P and Ir according to Brito and Abreu[2]

	Burnt cane			
No.	U	P	Ir	Ir Predicted
1	0.97	1,5	6,1	>6
2	0.90	2,2	2,7	3,0
3	0.89	2,1	3,6	3,0
4	0.89	0,3	2,4	2,0
5	0.85	1,7	2,4	2,0
6	0.81	0,4	0,4	1,4

The analysis of these results shows that the operator is generally skillful. His skill is manifested in the improvement of the quality of the cane in 15-20% for the same loss. Brito attributes the above to the fact that the operator concentrates his full attention on cutting the top, which was the only thing he did with the machine.

From this analysis it is inferred that maybe the shaded area could be widened up to uniformities of 0.6–0.7 with favorable distributions and depending on the skill of the operator. The scheme worked out allow not only for the determination of the general possibilities for using the topper but also for the prediction of the results to be expected in each concrete case. It could even be used as a device for controlling the work of the operator of the combine and eventually establish wage scales based on quantity as well as quality, that is to say, low loss index and high CIMe index.

CONCLUSIONS

1. A system of equations modelling a sugar cane stool was established to foresee the effects of a topper, cutting at fixed heights.

2. It was determined that fields with a uniformity of 0.75 constitute the limit of application of the topper unit, and that by using it the quality index in green cane could be tripled and this could be increased sixfold in burned cane, with losses lower than 3%.

3. A nomogram was designed which allows one to predict the results obtained

by using a topper in concrete cases and to norm the work of the combine operator.

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UN MODELO MATEMATICO DE UN CAMPO DE CAÑA DE AZUCAR PARA PREDECIR LOS RESULTADOS DE UN CUCHILLO DESCOGOLLADOR.

Jorge Lodos y Eduardo Casanova

RESUMEN

Se discute un modelo matematico de un campo de caña de azúcar para predicir los resultados de uno cuchillo descogollador.

Las ventajas del uso del descogollador son establecidas a base de este modelo. El promedio de uso, en terminos de uniformidad del campo y las perdidas de caña se determina mediante el desarrollo de un nomogramo durante el transcurso del estudio. La uniformidad minima permitida es 0.60; con perdidas hasta 5%.

Se recomienda un nomogramo para prognosticar los resultados del descogollador y establecer normas de trabajo para el operario.

EVALUATION OF SOME PERFORMANCE PARAMETERS OF THREE COMBINE HARVESTERS OF SUGARCANE (SACCHARUM OFFICINARUM)

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ABSTRACT

To evaluate the raw-material quality supplied for combine harvesters, SANTAL–115 (M1), TOFT R–300 (M2), and MF–201 (M3), were subjected to six Test Trials (TT). The variety was Co331, an erect cane, planted in a row spacing of 1.40 m, with a stalk density in the cane row ranging from 4.47 to 16.85 kg/m. The soil was Latosol Red Yellow, sandy phase, and textural natural sandy grouping with a field gradient of less than 2% and moisture soil conditions ranging from 5.09 to 9.85% at the time of trial. From the data obtained from TT, the following was determined: Total Extraneous Material Index (TEI%); Top Index (TI%); Leaf and Dry Leaf Index (LI%); Root Index (RI%) Soil Index (SI%); and Non-Selected Material Index (NI%), parameters of Efficacy of Manipulation (EM%), Effective Capacity (EC), "Practical" Effective Capacity (EC'), Frequency of Length of Chopped Canes (F%), were evaluated. Statistical analysis of the values found included the comparisons among means by the method of Tukey. Each index was analyzed separately by verifying harvester effects in Test Trials and harvester x TT interaction.

The mean indices obtained (Tukey 5%) by harvesters were as follows:

– M1 (TEI% = 9.64; TI% = 4.61; LI% = 1.43; RI% = 0.68; SI% = 1.28 and NI% = 0.92);

M2 (TEI% = 7.71; TI% = 4.61; LI% = 1.26; RI% = 0.41; SI% = 0.61 and NI% = 0.82); and

M3 (TEI% = 9.93; TI% = 6.74; LI% = 1.78; RI% = 0.32; SI% = 0.59 and NI% = 0.49).

Efficacy of Manipulation was non-significant among harvesters,

ranging from 74.9 – 92.0 (SANTAL–115); 72.0 – 94.5 (TOFT R–300), and 75.0 – 93.5 (MF–201) in all Test Trials (TT). All EC were affected by field conditions. In the TT R3, EC was lower than the rest. SANTAL–115 presented the lowest EC differing from others. On the other hand, the rests were non-significant between them. All EC' had similar behavior as EC. TOFT R–300 presented the best performance. The others presented similar performances.

INTRODUCTION

In Brazil, until the end of the harvest 77/78, a total of 338 combine harvesters were already performing. According to PLANALSUCAR estimates, an area of 125, 104 ha were harvested during this time by those combine harvesters. The most predominant models on the Brazilian market are: SANTAL–115; MF–201 and TOFT R–300. On the other hand, the majority of the field trials carried out for the present has not followed a uniform methodology and not always a more efficient control on the various factors involved in the performance has been observed. This has caused difficulty to define parameters for evaluation of combine harvester performance in Brazil, aiming at studies for comparative performances.

The present study aimed to define and evaluate parameters of operational performance related to the raw-material quality harvested by the most used combines in this country, under similar operational field conditions.

EXPERIMENTAL PROCEDURE

The combine harvesters tested were: SANTAL–115; TOFT R–300 and MASSEY FERGUSON–201, coded M1, M2 and M3, respectively. The variety was Co331, an erect cane, according to the criterium proposed by Ripoli *et al*[3]; the burn occurred between 12 and 14 hours before the trials, considered "bad", according to the criterium proposed by Balastreire and Ripoli[1]; inter-row spacing was 1.40 m and furrow length ranged from 220 to 250 m; field gradient was less than 2%; and the soil was Latosol sandy phase, a textural natural sandy grouping.

Cane rows were levelled, resulting to absence of furrows. Table 1 shows other culture conditions for each Test Trial, coded by TT. Rear dumping trucks to collect samples, cronometer, weighing balance, plastic bags, stakes, tape measures, a 6 mm mesh sieving, tarpaulin, wood triangle and knives, were also utilized. Each combine harvester was conducted by a single experienced operator in all TT.

Culture Conditions

For culture conditions in all six TT, a criterium proposed by Ripoli *et al*[3] was used, considering the following aspects; means stalk length, mean stalk density/linear meter (in kg/linear meter and in number of stalks/linear meter); stand cane field; burn quality; moisture soil conditions (in the first superficially 10 cm); soil

granulometer and age level of culture ripening.

a. Mean Stalk Length

Sixty stalks were taken at random in the area of each TT, being twenty in the rows where each combine harvester has performed. Height of the bottom of the first internode was measured (to soil level) to the first visible dewlap in the leaf of each stalk, by determining the arithmetic mean of the obtained length.

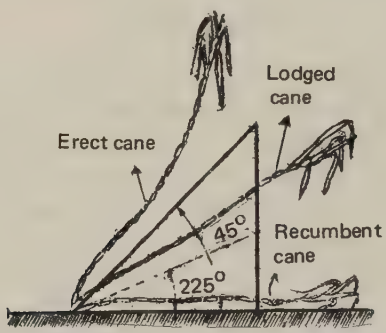

FIGURE 1. Standard triangle for quantitative evaluation of the sugarcane stand

b. Mean Stalk Density/Linear Meter

Twenty randomized samples in each TT were taken (a total of 120 samples). Each sample is formed by counting existing stalks in 10 linear meters. Only milling stalks were considered, therefore, "sucking shoots", deteriorized stalks, etc., were not computed. The arithmetic mean of samples were then determined.

For a careful evaluation of stalk density in terms of kg/linear meter, the following was determined: weight of chopped stalks harvested by the combine which was then added up to the proportional weight obtained by the stalk non-harvested, and the total was divided into the corresponding furrow length.

c. Stand Cane Field

Stand cane field refers to erect, lodged and recumbent stalks in the rows and the respective stalk density in each situation. The standard rectangular triangle was employed for this quantity, proposed by Ripoli *et al*[3], whose criterium of specification for the erect, lodged and recumbent stands are shown in Fig. 1.

Twenty samples were taken at random from one meter of furrow length by TT (a total of 120 samples), by employing the standard triangle at the bottom of each existing stalk within this space. The number of the erect, lodged and recumbent canes was recorded and each condition determined by percentage.

d. Burn Condition

The criterium of qualifying burn was adopted with only two options: good or bad, according to Balastreire and Ripoli[1]. Burn is considered good when only stalks and the top remain, and is bad when leaves, dry leaves, culture remnants and weeds remain, aside from stalks and the top.

e. Moisture Soil Conditions

Fifteen soil samples were taken for each TT (5 samples per harvester tested), at 0-10 cm in depth, according to the methodology proposed by Ripoli *et al*[3]. The samples were taken at random soon after the harvester performance in the cane row. Moisture content (dry basis) was determined by drying up in an oven at 105-110°C, for 48 hours.

f. Soil Granulometry

The same samples referred to the previous item were also used for soil granulometric analysis. Each 15 samples corresponding to the same TT was mixed and homogenized, taking from there a compound sample. The clay fraction was determined by the pippette method adopted by Steel and Bradfield[4], and the sandy fraction was separated by the humid sieving (sieve 270 – diameter 0.053 mm) and then fractioned by a dry sieving. After that, a textural soil group was determined, according to the diagram proposed by USDA Soil Survey.

g. Age and Degree of Culture Ripening

The sugarcane field age was obtained by means of information of the agricultural section of the sugarmill where trials were carried out. Ripening degree was obtained by means of a cane field refractometer in 10 readings per TT, by taking the average of 10 randomized readings.

Combine Harvester Test

Evaluation of the operational performance of harvesters in each TT covered the following determination, according to Mialhe and Ripoli[2].

a. Total Extraneous Material Index (TEI%)

The total extraneous material index (TEI%) is an indicator of percentage of extraneous material in weight, contained in the product at the end of harvest (on infield transport). "Tops", leaves and dry leaves, soil, roots and non-selected material are considered extraneous materials.

The total extraneous material index is expressed by the equation:

$$TEI\ \% = \frac{TE}{S} \cdot 100$$

where:

TE = total quantity in weight, of extraneous material contained in sample S (kg).

S = samples harvested by the combine and loaded in the truck (kg)

b. Top Index (TI %)

It is expressed by the equation:

$$TI\ \% = \frac{T + t}{S} - 100$$

where:

t = quantity, in weight, of tops aggregate to all chopped canes contained in samples S (kg).

T = quantity, in weight, of free tops contained in samples S (kg).

c. Leaf and Dry Leaf Index (LI %)

It is expressed by the equation:

$$EI\ \% = \frac{DL}{S} - 100$$

where:

DL = quantity, in weight, of leaves and dry leaves contained in sample S (kg).

d. Root Index (RI %)

It is expressed by the equation:

$$RI\ \% = \frac{RO}{S} - 100$$

where:

RO = quantity, in weight, of roots contained in sample S (kg).

e. Soil Index (SI %)

It is expressed by the equation:

$$SI\ \% = \frac{SO}{S} - 100$$

where:

SO = quantity, in weight, of roots contained in sample S (kg).

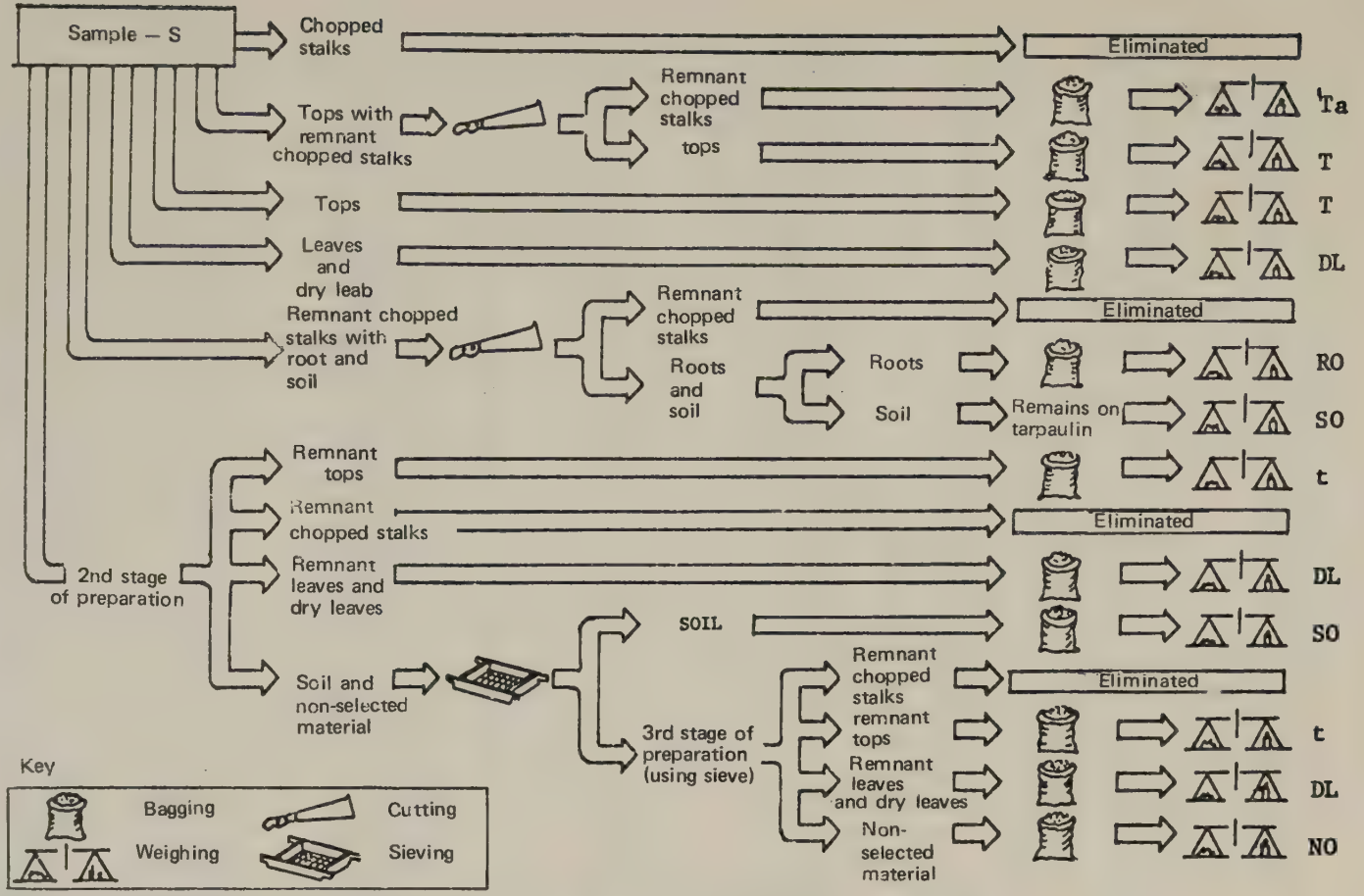

FIGURE 2. Flow chart of separation of the extraneous material contained in sample S.

f. Non-Selected Material Index (NI%)

This index result from the general process for separation due to the size of its components. It is expressed by the equation:

$$NI\% = \frac{NO}{S} - 100$$

where:

NO = quantity, in weight, of remaining material from separation and non-selected (kg.).

g. Scheme of Sample Separation

To obtain indexes described from a tof, weighing determination of different sample S components is demanded. For that, a scheme of separation, which is illustrated in the flow chart in Fig. 2, is established.

h. Efficacy of Manipulation (EM%)

Efficacy of Manipulation (EM%) is defined, according to Mialhe and Ripoli[2], as a ratio between the chopped cane (CC) at the end of harvest (on infield transport) and the estimated stalk density (SD) presented in the cane row, in its natural state, or:

$$EM\% = \frac{CC}{SD} - 100$$

Chopped cane at the end of harvest (CC) was obtained by means of separation and weighing sample S, or:

$$CC = S - TE$$

where:

TE is the quantity of extraneous material contained in sample S.

The estimated quantity of stalk density (SD) contained in the cane row in its natural state, is determined by considering the following aspects: quantity of cane "in natura" (C_{in}) in the field, is equivalent to a determined quantity of chopped canes (CC) associated with the extraneous material (TE), or:

$$C_{in} = SD + TE$$

After the cane is harvested by the combine, part of SD is effectively harvested and transformed into CC, and the other is lost in the sugarcane field, being the amount of losses (L):

$$SD = CC + L$$

Thus, the denominator of the equation (I), is obtained by summing the quantity of chopped canes (CC) in the sample S, free of extraneous material (TE), with the quantity of chopped canes lost in the sugarcane field for each of the cane row in the trials, equivalent to a replication.

In the trials, the data for evaluation of EM% was obtained by using the following sequences:

1) in a cane row, of a previously known length, a certain harvester and the infield transport were employed; the harvester moved at the maximum speed permitted by the cane row conditions;

2) after harvesting the cane row, the following was determined: – *in the sugarcane field:* sampling for determination of losses of cane in the field; *in the sugarmill yard:* determination of the net load (sample), separation of the extraneous material and determination of the weight of chopped canes (CC);

3) Sampling of losses in the sugarcane field was performed as follows: 5 randomized samples were taken, of 10 m in length/1.4 m in width over the cane row harvested, obtaining therefore, an area of 14 m^2/sample.

In each Test Trial (coded by TT), 4 cane rows were harvested per tested combine, totalling 20 samples of losses per harvest and per TT.

Within the corresponding area for each sample, all stalks were collected, or the chopped canes that were not harvested by the combine. Furthermore, in the ratooning, by means of knives, the remnants of the remaining stalks were cut. All of these materials were bagged and weighed, and their value in the field card was recorded.

For each group of 5 samples corresponding to a single cane row, the total weight of the harvested material was then summed. This value corresponds to losses at 70 m^2 of the sampled a ea. By associating this data with the cane row harvested, an estimated of losses (L) in the sugarcane field was obtained.

i. Effective Capacities – EC and EC'

Two methods for evaluation of this parameter were adopted, according to Mialhe and Ripoli, who expressed the Effective Capacity (EC) as product of effective speed of movement of the harvester in the cane row (E_S), stalk density at the same (SD) and the Efficacy of Manipulation (EM%), or:

$$EC = E_S - SD - EM$$

where:

EC = Effective Capacity (kg/s)

ES = Effective speed (m/s)

SD = Stalk density in the cane row (kg/m)

EM = Efficacy of Manipulation (%)

The second method is the commonly adopted in practice and defines the "Practical" Effective Capacity (EC') as a ratio between quantity of material har-

vested by the combine (CC + E) over the corresponding time harvest taken, or:

$$EC' = \frac{CC + TE}{Th} = \frac{S}{Th}$$

where:

EC' = "Practical" Effective Capacity (kg/s)

DD = Total of chopped cane harvested (kg)

TE = Total of extraneous material together with CC (kg)

S = CC + TE = Total sample harvested (kg)

Th = Harvest time in the cane row

j. Frequency of Length of Chopped Canes (F%)

To evaluate the variation in the length of chopped canes, randomized samples of 200 units each, were taken and the length of each chopped cane measured with the precision of 0.5 cm S. Thus, 30 samples were taken in the last five TT, totalling 6,000 (six thousand) chopped canes. For replications of each harvester, the respective polygons of frequency were constructed by considering intervals of frequency of 5 cm.

For each harvester in each TT, two randomized replications were taken. Each replication consisted of the total weight of the material harvested by the combine (chopped cane – CC + TE).

When the cane row which corresponds to a single replication was harvested, the infield transport took all samples to the sugarmill balance obtaining the net income of the samples. After this weighing, the sample was unloaded on a tarpaulin (Fig. 3), where separation of the extraneous material and a posterior weighing of the components were determined, coded by: T = free tops; DL = leaves and dry leaves; SO = soil, Ta = remnants of chopped cane not eliminated initially; t = remnants of tops aggregate to chopped cane remnants (Fig. 4); RO = roots (Fig. 5); NO = non-selected extraneous material (Fig. 6).

The total weight of extraneous material, subtracted from the total weight of sample S, furnished the net income of chopped canes, the milling material.

Regarding soil index, the weight considered for calculation was not the originally determined by the balance because this value was referred to soils with a determined moisture content. Therefore, the values considered were for dry soil obtained as described in i.e.

All determination of this study was obtained with two decimal fractions. After the statistical analysis, a rounding up to one decimal fraction is accomplished.

FIGURE 3. Sample (S) unloaded in tarpaulin for separation of extraneous material.

FIGURE 4. Separation of top fractions contained in chopped canes.

FIGURE 5. Separation of roots contained in chopped canes.

FIGURE 6. Third stage of separation, remaining the material non-selected due to its small size.

RESULTS AND DISCUSSIONS

Total Extraneous Material Index (TEI%)

Variance analysis of TEI% data showed: a) a significant effect (at 1% level of probability) for harvesters and Tests Trials (TT), and b) a non-significant effect for harvester x TT interaction.

The lower and higher values observed for TEI% in TT, shown by harvesters were as follows:

Harvesters	Lower and Higher Values of TEI%	Average
M1 (SANTAL)	5.5 – 15.6	9.64
M2 (TOFT)	3.8 – 12.8	7.71
M3 (MF)	6.7 – 14.9	9.93

LSD (Tukey 5%) = 1.30

Comparisons among means reveal that harvester M2 showed TEI% lower than the other harvesters. Harvesters M1 and M3 were non-significant in relation to TEI%.

Mean values for TEI% observed between TT were as follows:

TT	Average (3 harvesters)	TT	Average (3 harvesters)
R1	8.88	R4	7.14
R2	11.04	R5	6.26
R3	13.79	R6	7.45

LSD (Tukey 5%) = 2.30

Comparisons among means reveal that TEI% for the tested harvesters was affected by the trial conditions (differences among TT). In the TT R4, R5 and R6, the lowest values of TEI% were observed.

The non-significant TT x harvester interaction deduces that the harvester performance did not vary from one TT to other. Harvester M2 showed the lowest TEI% indexes in all TT.

Top Index (TI%)

Variance analysis of TI% data revealed: a) a significant effect (at 1% level of probability) for harvesters and Test Trials (TT) and b) a non-significant effect for harvester x TT interaction.

The lower and higher values observed for TI% in TT shown by harvesters were as follows:

Harvesters	Lower and Higher Values of TI%	Average
M1	3.3 – 11.0	5.31
M2	2.0 – 9.2	4.61
M3	4.2 – 11.2	6.74

LSD (Tukey 5%) = 1.06

Comparisons among means revealed that harvester M3 showed, on the average, a higher TI% than harvesters M1 and M2. Between harvesters M1 and M2, TI% is not defined statistically.

Mean values observed for TI% among TT were as follows:

TT	Average (3 harvesters)	TT	Average (3 harvesters)
R1	5.54	R4	4.78
R2	4.74	R5	4.31
R3	9.94	R6	4.00

LSD (Tukey 5%) = 1.87

Comparisons among means reveal that TI% for the tested harvesters were affected by the conditions of each TT. Comparisons among means reveal that TT R3 showed a higher TI% and was significant in relation to the others. The remaining TT were non-significant between them.

Leaf and Dry Leaf Index (LI%)

Variance analysis of LI% data revealed that a significant effect (at 5% level of probability) for harvesters; for TT (at 1% level of probability) and harvester x TT interaction (at 5% level of probability).

The significant effect for harvester x interaction in the variance analysis took the decomposition of its number of degrees of freedom. The new variance analysis revealed for harvesters only in TT R2 and R6.

The lower and higher values observed for LI% in TT, shown by harvesters were as follows:

Harvesters	Lower and Higher Values of LI%	Average
M1	0.4 – 3.5	1.43
M2	0.4 – 7.8	1.26
M3	0.6 – 3.0	1.78

LSD (Tukey 5%) = 0.59

Comparisons among means through Tukey test (5% of probability) showed that: a) in the TT R2, the harvester M1 presented a higher LI% than harvester M2. Harvester M3 presented an intermediary performance between M1 and M2 and was non-significant in relation to them; b) in the TT R6, the harvester M3 presented a higher LI% than the others, i.e., presented the worst performance; c) in the remaining tests, non-significant differences among harvesters were shown.

Mean values observed for LI% in TT groups were as follows:

TT	Average	TT	Average
R1	1.59	R4	0.92
R2	2.63	R5	0.52
R3	1.29	R6	1.00

LSD (Tukey 5%) = 1.04

Root Index (RI%)

The variance analysis of RI% data revealed that: a) a significant effect (at 1% level of probability) among harvesters and for Test Trials (TT); b) a non-significant effect for harvester x TT interaction.

The lower and higher values observed for RI% in TT, shown by harvesters were as follows:

Harvesters	Lower and Higher Values of RI%	Average
M1	0.2 – 1.2	0.68
M2	0.0 – 1.0	0.42
M3	0.1 – 0.7	0.32

LSD (Tukey 5%) = 0.28

Comparisons among means revealed that harvester M1 presented, on the average, a higher RI% than the others. Between harvesters M2 and M3, RI% was non-significant.

Mean values observed for RI% among TT were as follows:

TT	Average (3 harvesters)	TT	Average (3 harvesters)
R1	0.26	R4	0.36
R2	0.68	R5	0.54
R3	0.22	R6	0.80

LSD (Tukey 5%) = 0.50

The significant effect for TT revealed that RI% for harvesters was affected by the culture conditions of TT. The composition of averages revealed that in the TT R3, a lower RI% average was shown.

The non-significant interaction among harvesters x TT in terms of RI% indicates that the performance among harvesters did not vary from one TT to other, i.e., harvester M1 presented a higher RI% than the remaining in all TT.

Soil Index (SI%)

The variance analysis of SI% data revealed that: a) a significant effect (at 1% level of probability) for harvesters, for TT and for harvester x TT interaction.

The significant effect for harvester x TT interaction in the variance analysis took the decomposition of its number of degrees of freedom. The new variance analysis revealed significance for harvesters in the TT R1 and R2. Such a fact indicates a variation of performance among harvesters, in terms of SI%, from one TT to other.

In the TT R1 and R2, the harvester M1 presented a higher SI% than harvester M2. In the remaining TT, there were non-significant differences among harvesters.

The lower and higher values observed for SI% in TT presented by harvesters were as follows:

Harvesters	Lower and Higher Values of SI%	Average
M1	0.5 – 3.9	1.28
M2	0.1 – 1.7	0.61
M3	0.3 – 1.1	0.59

LSD (Tukey 5%) = 0.02

Comparisons among means revealed that harvester M3 presented a lower SI% than the remaining. Harvester M2 and M3 were non-significant between them, but were both significant in relation to M1, which presented the highest SI%.

Mean values observed for SI% between TT were as follows:

TT	Average	TT	Average
R1	0.32	R4	0.40
R2	2.18	R5	0.47
R3	0.56	R6	1.04

LSD (Tukey 5%) = 0.04

Comparisons among means reveal that SI% for the tested harvesters were affected by trial conditions (differences among TT). In the TT R1, R4 and R5, the lower values for SI% were observed.

Non-Selected Material Index (NI%)

Variance analysis of NI% data revealed a significant effect for harvesters, for TT and for harvester x TT interaction (at 1% level of probability). The significant effect for harvester x TT interaction caused the decomposition of its number of degrees of freedom. The new analysis of variance revealed significance for harvesters in the TT R2, R3 and R4, indicating a variation in performance among harvesters, in terms of NI% from one TI% to other.

The lower and higher values observed for NI% in TT, presented by harvesters were as follows:

Harvesters	Lower and Higher Values of NI%	Average
M1	0.1 – 2.5	0.92
M2	0.2 – 1.9	0.82
M3	0.2 – 1.0	0.49

LSD (Tukey 5%) = 0.10

Comparisons among means revealed that harvester M3 presented the lowest NI%, and was significant relating to the remaining. Harvesters M1 and M2 were non-significant between them.

Mean values observed for NI% between TT were as follows:

TT	Average	TT	Average
R1	0.16	R4	0.68
R2	0.81	R5	0.45
R3	1.78	R6	0.57

LSD (Tukey 5%) = 0.34

Comparisons among means revealed that NI% for the tested harvesters was affected by the trial conditions (differences among TT). In the TT R1, R4 and R5, the lowest NI% values were observed.

Efficacy of Manipulation (EM%)

The variance analysis of EM% data revealed a non-significant effect among harvesters and for harvester x TT interaction, and a significant effect for TT (at 1% level of probability).

The lower and higher values observed for EM% presented by harvesters were as follows:

Harvesters	Lower and Higher Values of EM% (t/h)	Average
M1	74.9 – 92.0	84.64
M2	72.0 – 94.5	84.59
M3	75.0 – 93.5	84.98

LSD (Tukey 5%) = 4.59

Comparisons among means revealed that there was no significant differences among harvesters. All three harvesters had the same performance under the different conditions of all six TT.

The non-significant harvester x TT interaction determines that the performance of harvesters did not vary from one TT to other, i.e., for each TT, all harvesters had the same performance.

The significant effect for TT reveals that EM% for the tested harvesters was affected by the conditions of TT. In the TT R5 and R6, EM% was higher than the remaining TT, despite the non-significant difference which occurred between R5 and R6, as well among the remaining TT.

Mean values observed for EM% among TT were as follows:

TT	Averages (t/h) (3 harvesters)	TT	Averages (t/h) (3 harvesters)
R1	83.16	R4	81.33
R2	82.07	R5	91.58
R3	78.69	R6	91.60

LSD (Tukey 5%) = 8.09

The non-significant harvester x TT interaction indicates that in terms of EM%, there was no variation of performance among harvesters. For each TT, all 3 harvesters had the same performance among harvesters, from one TT to other.

In short, the tested harvesters presented, on the average, EM% values from 75.8 to 93.9, causing losses of milling raw-material from 6.1 to 24.2%.

Effective Capacity (EC)

The variance analysis of Effective Capacity (EC) data revealed a significant effect for harvesters and for TT (at 1% level of probability) and for harvester x TT interaction (at 5% level of probability).

The significant effect for harvester x TT interaction took the decomposition of its number of degrees of freedom. The new variance analysis revealed significance to the 1% level of probability for TT R5 and at 5% level of probability for the TT R3 and R6, indicating a variation of performance among harvesters, in terms of one TT to other.

The lower and higher values observed for TT, presented by harvesters were as follows:

Harvesters	Lower and Higher Values of EC (t/h)	Average (t/h)
M1	21.2 – 42.8	33.30
M2	23.4 – 57.6	43.63
M3	35.3 – 50.0	42.55

LSD (Tukey 5%) = 6.44

Mean values observed for EC among TT were as follows:

TT	Averages (t/h) (3 harvesters)	TT	Averages (t/h) (3 harvesters)
R1	38.81	R4	39.56
R2	43.42	R5	46.76
R3	27.04	R6	46.69

LSD (Tukey 5%) = 11.38

Comparisons among means showed that in the TT R3, a lower EC of harvesters was observed, therefore, there was no significant difference of EC among harvesters.

In the RR R6, it was verified that the harvester M1 presented an EC lower than harvester M2. The performance of harvester M3 was non-significant in relation to harvesters M1 and M2. In the remaining TT, the performance among harvesters, in terms of TT was non-significant.

"Practical" Effective Capacity (EC')

The variance analysis of "Practical" Effective Capacity (EC') data revealed a significant effect for harvesters (at 5% level of probability), and for Test Trials and harvester x TT interaction (at 1% level of probability).

The significant effect for harvester x TT interaction took the decomposition of its number of degrees of freedom. The new variance analysis revealed significance at 1% level of probability in all TT, indicating that the variations of field conditions among TT affected EC' of the harvesters.

The lower and higher values observed for EC' presented by harvesters were as follows:

Harvesters	Lower and Higher Values of EC' (t/h)	Average
M1	24.8 – 49.0	36.18
M2	30.6 – 64.8	49.54
M3	36.7 – 59.8	47.63

LSD (Tukey 5%) = 3.02

Comparisons among means showed that the harvester M1 presented the lowest EC', being significant in relation to harvesters M2 and M3. These were non-significant between them.

Mean values observed for EC' among TT were as follows:

TT	Averages (t/h) (3 harvesters)	TT	Averages (t/h) (3 harvesters)
R1	44.46	R4	45.14
R2	50.27	R5	44.86
R3	31.07	R6	50.90

LSD (Tukey 5%) = 5.26

Comparisons among means revealed that in the TT R3, the lowest EC' of harvesters was observed and in the TT R6, the highest EC'.

Frequency of Length of Chopped Canes (F%)

The data analysis of length of chopped canes covers the study of distribution of frequencies for each harvester in the last five TT. From these data, polygons of frequency for each harvester were constructed, as shown in Fig. 7. By comparing the polygons, it is observed that the harvester M2 presented a higher variability in the distribution of frequency of length of chopped canes among the remaining TT, than the harvesters M1 and M3.

The intervals of group of length of chopped canes that presented a higher frequency in the TT were as follows:

Harvester	Intervals of Group of Higher Frequency (cm)	TT
M1	25 – 30	R2 to R6
M2	25 – 30	R2, R3 & R6
M3	20 – 25	R4, R5
	25 – 30	R2 to R6

The results showed that harvesters M1 and M3 presented a very satisfactory uniformity, on the contrary to M2.

CONCLUSIONS

Total Extraneous Material Index (TEI%)

Harvester M2 presented the lowest TEI%, independently of trial conditions.

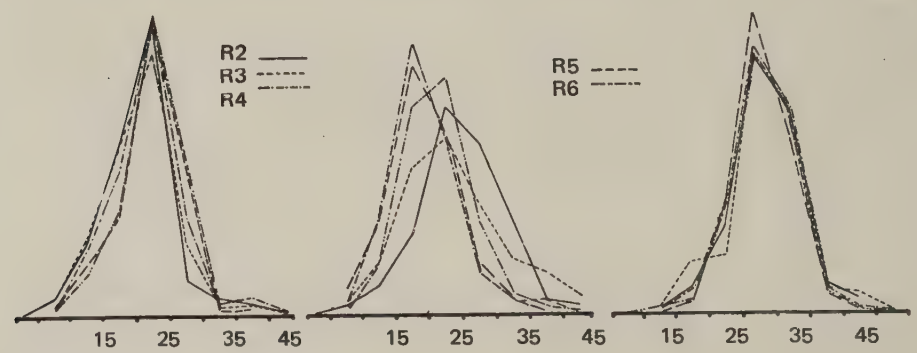

FIGURE 7. Polygons of frequency of length of chopped cane, for combines M1 (SANTAL–115), M2 (TOFT R–300) and M3 (MF–201) in the last five Test Trials (TT).

The TEI% values presented by harvesters M1 and M3 were non-significant between them. Due to differences of TT, variations of trial conditions affected the TEI% value presented by the tested harvesters. From all previous conclusions, it is evident that the harvester M2 presents more efficient cleaning mechanisms than the others. The cleaning mechanisms of harvesters M1 and M2 are equivalent. In all harvesters, the cleaning performance is affected by the variation of field conditions.

Top Index (TI%)

Harvester M3 presented the highest TI%, independently of trial conditions. The values of TI% presented by harvesters M1 and M2 were non-significant between them. Due to differences of TT, variations of trial conditions affected the value of TI% presented by harvesters.

From previous conclusions, harvesters M1 and M2 showed better conditions of top elimination than harvester M3.

Leaf and Dry Leaf Index (LI%)

Harvester M2 presented an intermediary LI% between harvesters M1 and M3. Harvesters M1 and M3 appear to be susceptible to field conditions in the different TT; it was observed that TT R2 presented a higher LI% than harvester M1 and in TT R2, higher LI% for harvester M3.

Root Index (RI%)

Harvester M1 presented a higher RI%, independently from trial conditions. Values of RI% presented by harvesters M2 and M3 were non-significant. Due to TT, variation of trial conditions affected the RI% value presented by the tested harvesters.

From previous conclusions, it is evident that harvesters M2 and M3 showed mechanism of basal cutting adapted to conditions under which trials in relation to harvester M1 were carried out. There were no differences in performance between harvesters M2 and M3.

Soil Index (SI%)

Harvester M1 presented in two of the TT a higher SI% than the remaining and in the other TT, a performance similar to the harvesters M2 and M3.

Non-Selected Material Index (NI%)

Harvester M3 presented in two of the TT a lower NI% than the remaining and in the other TT a similar performance to the harvesters M2 and M1.

The harvesters were non-significant among them in all TT regarding Efficacy of Manipulation (EM%). EM% presented significant variations under the different field conditions favored by all TT.

It is evident, therefore, that EM% varies depending upon the field conditions, when harvesters are conducted by properly experienced operators.

Effective Capacity (EC) of harvesters were affected by field conditions; in the TT R3, EC of harvesters was lower than the remaining RR. The harvester M1 presented a lower EC than harvesters M2 and M3. It was observed that EC of harvesters M2 and M3 were non-significant.

"Practical" Effective Capacity had the similar behavior as Effective Capacity (EC). In the TT R3, EC' of harvesters was lower than the remaining TT The harvester M1 presented a lower EC' than others.

Harvesters M1 and M3 presented the lowest variability in the distribution of frequency of length of chopped canes (F%) in the last five TT. The lowest frequency of length of chopped canes was between 25 – 30 cm.

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EVALUACION DE ALGUNOS PARAMETROS DE FUNCIONAMIENTO DE TRES COSECHADORAS COMBINADAS DE CAÑA DE AZUCAR *(SACCHARUM SPP.)* IN ALAGOAS, BRAZIL Ira. PARTE

T.C. Ripoli and L.G. Mialhe

RESUMEN

Con el fin de evaluar la calidad de materia cruda suplida, las cosechadoras combinadas SANTAL–115 (M1), TOFT R–300 (M2),

y MF–201 (M3) fueron sometidas a seis pruebas de comprobacion en campos de condiciones similares. Se uso la variedad Co331, Caña erecta, sembrada en hileras espaciadas a 1.40 m, con una variacion de densidad de tallos por hilera de 4.47 a 16.85 kg/m. Al tiempo de la prueba el terreno era Latosol Rojo Amarillo, en su fase arenosa, y textura natural de agrupacion arenosa con gradiente de campo menor de 2% y variacion de humedad del terreno de 5.09 a 9.85% al tiempo de la prueba. De los datos obtenidos de la prueba se determino lo siguiente. Indice Total de Materia Extraña (%ITME); Indice Superior (%IS); Indice de Hojas y Hojas Secas (%HS); Indice de Raiz (%IR); Indice de Terreno (%IT) e Indice de Material No Seleccionado (%IN). El analisis estadistico de valores encontrados incluyo comparaciones entre medios del metodo Tukey. Cada indice fue analizado por separado, verificando los efectos de la cosechadora en la Prueba de Comprobacion e interactivo en la cosechadora x TT.

Los indices de medios obtenidos (Tukey 5%) por las cosechadoras son como sigue:

M1 (%ITME = 9.64; %IS = 4.61; %HS = 1.43; %IR = 0.68; %IT = 1.28; y %IN = 0.92);

M2 (%ITME = 7.71; %IS = 4.61; %HS = 1.26; %IR = 0.42; %IT = 0.61 y %IN = 0.82; y

M3 (%ITME = 9.93; %IS = 6.74; %HS = 1.78; %IR = 0.32; %IT = 0.59 y %IN = 0.49).

WIDE BASE FURROW FOR SUGARCANE PLANTING

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ABSTRACT

Planting three sugarcane varieties in wide base furrow with 30 cm internal opening and 1.80 m, 2.00 m and 2.20 m spacing increased yield for five consecutive years, as compared with conventional furrows, 1.50 m apart. Furrowing between 1.70 m and 1.80 m permits passage of vehicles using only the interlines without damaging the ratoons by soil compaction. Sugarcane planting in wide base furrows is suited for control of transport vehicles in the cultivated area.

INTRODUCTION

In 1979, the authors presented results obtained in the first four harvests of studies on row spacing. There were no significant differences in the final yields among three treatments with wide base furrows and conventional furrows with 1.5 m distrance.

Differing from the results obtained in other studies correlating planting spaces and yields, the wide base furrowing is a new practice which can be used in different sugarcane culture aspects.

Since the sugarcane yield levels were maintained in different treatments for five harvests, the effects of climatic factors were considered. This permits the study of the correlation among planting spaces and passage of transport vehicles into the area being cultivated, an aspect of fundamental importance with emphasis on soil compaction.

In the present report the fifth harvests are presented and the results of five successive harvests discussed.

MATERIALS AND METHODS

Plant Cane

The experiment was carried out in Out/73, in Darc Red Latossoil of Sao Martinho Sugar Mill, State of Sao Paulo. Fig. 1 shows schematically the common and wide base furrow.

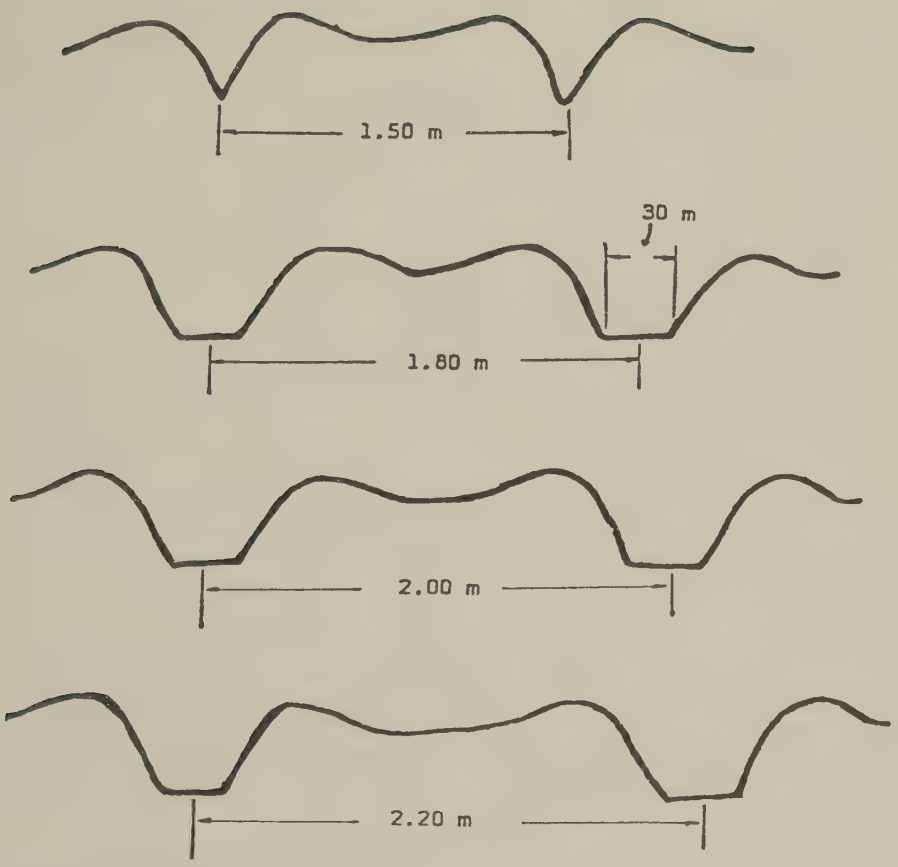

FIGURE 1. Spacing of single and wide base furrows

The varieties IAC52/326 , CB41-76 and CB44-52 were utilized, because they presented respectively high, medium and reduced budding levels as variety characteristics. The implement for opening wide base furrows was obtained through a little modification of conventional furrower-fertilizer implement, as shown in Fig. 2.

Table 1 shows the distances in meters of furrow per hectare, as well as the quantities of sugarcane seed and fertilizer used in several treatments.

It can be observed that in the wide base furrows 30% more of fertilizer were applied in relation to the single furrows with 1.50 m. space. The whole stalks were distributed one after another and divided in seedpieces with 3-4 buds, without phytosanitary treatment according to commercial practices.

Ratoons

The ratoons also received after each harvest 30% more fertilizer in the wide base furrows, compared with single furrows.

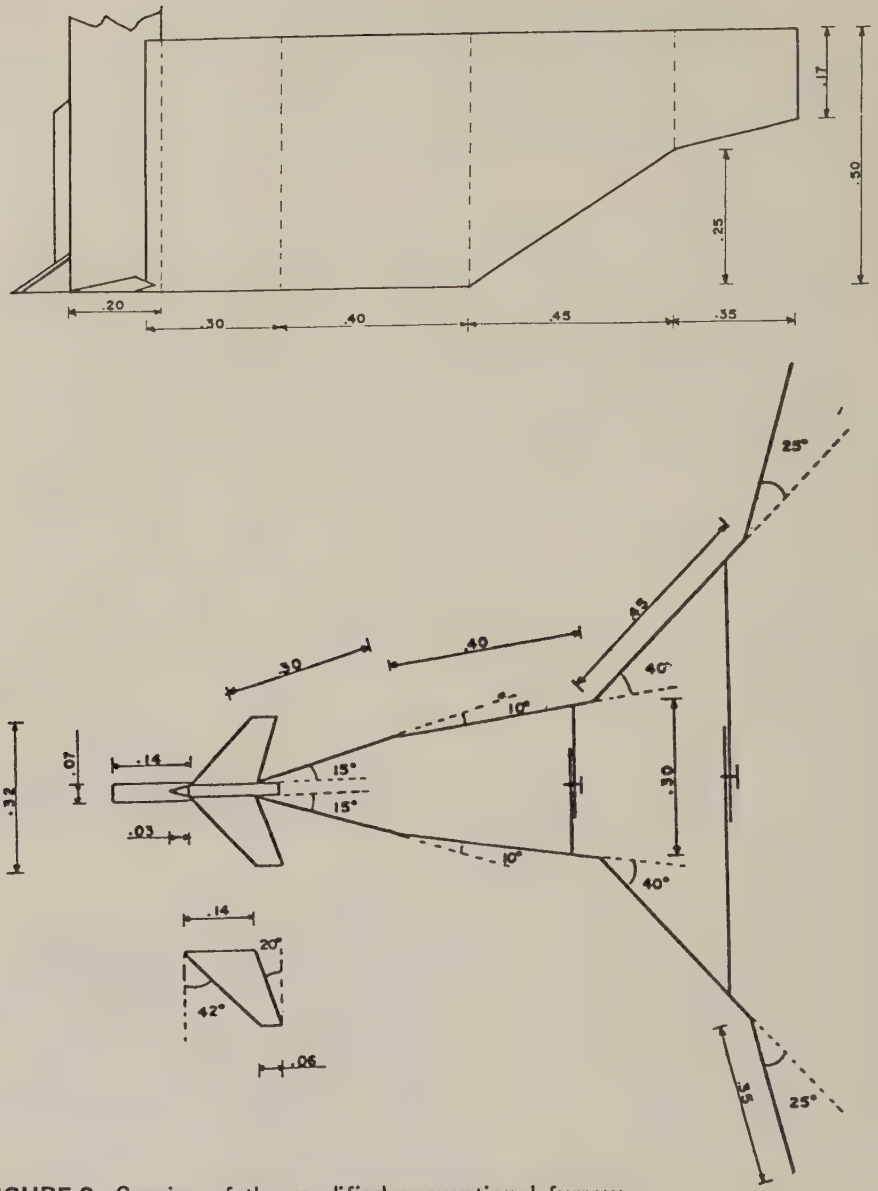

FIGURE 2. Spacing of the modified conventional furrow

As cultural tillering, a subsoiling operation 20-25 cm deep in both sides of sugarcane lines was made.

Sampling

To evaluate the productions, five replications in each treatment, with five

TABLE 1. Furrowing and fertilizer quantities

Furrow Types	Spacings	Meters of Furrow/ha	Cane in line	Fertilizer g/m of furrow	Fertilizer kg p/ha
Single	1.50	6,666	2	93	620
	1.80	5,555	3	121	672
Wide Base	2.00	5,000	3	121	605
	2.20	4,545	3	121	550

lines 30 meters long were weighed. Stalk amounts were cut in 25 central meters of the same five sugarcane lines. the replications followed the same places for five harvests.

To the technological analyses, four stalks of each replication were casually taken, resulting in a mixed sample with 20 stalks for each treatment.

RESULTS

All harvests were made when sugarcane was 12-13 months of age, although plant cane is traditionally harvested at 18 months. Unfavorable climatic conditions in 1974 contributed to the low yields of the first harvest. Table 2. shows the rain distribution observed in correspondent period of the first harvest.

DISCUSSION

Agronomic Aspects

Previous studies on spacings in sugarcane planting concluded that the yields are reduced as the distances between furrows are increased. Results obtained in the present work with wide base furrow planting maintained equivalent levels for several spacings in the respective agricultural cycles of each variety.

Variations in yearly yields were probably due to different climatic conditions in each agricultural period.

Only the treatment with 2.20 m of IAC52/326 variety showed significant difference compared with other varieties.

Referring to the treatments with single furrows 1.50 m apart (Table 4), the relative predominance in productivity in the two first harvests of 3 varieties can be observed. However, from the 3rd harvest on, successive decreases in yields of single furrows were observed affecting final average of 5 harvests. Probably unfavorable differences in the single furrows in the 5th harvest should have been more accentuated under normal climatic conditions in 1978.

TABLE 2. Rain distribution in the fifth (5th) harvest.

1977				1978								
OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
01–15.0	01– 2.4	01–19.5	01–14	04–14.0	01–20.0	16–24.0	16–16.9	08–20.00	15–29.7	0.0	01– 0.5	10– 5.5
05–10.0	07– 8.0	02–34.5		05– 0.3	02– 6.0	20– 9.5	17–19.0	20.00	17– 4.2		04– 0.3	13– 3.2
16– 1.0	11–23.5	03–20.7	01–15.0	05– 1.2	03–24.0	21– 6.5	18–33.5		20–15.7		05– 3.5	16– 5.2
17– 2.1	12– 9.7	04–34.5	02– 2.0	12–13.0	04– 0.7	23–11.0	20– 4.5		21– 9.8		07– 8.2	17– 0.5
25– 3.2	14–10.8	05– 9.2	03– 1.0	13– 6.0	05– 0.7	51.0	21– 3.6		59.4		16–30.0	18–38.3
27– 7.4	15– 4.5	07–16.8	04– 4.7	15–12.0	07–12.0		22–16.5				17– 4.4	19– 7.7
28– 0.5	16–17.8	09–40.0	05– 6.4	17–17.8	08– 9.5		20–13.7				44.9	28– 0.2
39.2	18–11.5	10–37.7	06–19.0	20– 38.2	09–48.5		30– 2.5					29– 9.0
	19– 7.8	17– 1.0	07– 0.2	21–70.5	10–25.0		31– 1.1					30– 7.3
	20–40.5	18– 5.5	08– 1.0	23–23.5	11– 0.7		111.3					31– 0.2
	21–38.5	19–18.0	09–26.0	25– 8.2	13– 5.0							76.1
	22– 1.0	20– 5.5	10–15.5	26–24.4	14– 0.5							
	24– 4.0	21– 5.0	11– 7.5	27– 2.0	24– 0.5							
	26– 2.0	22– 9.8	12–10.2	28– 8.0	29–21.0							
	27– 0.5	23–13.1	13–36.5	239.1	174.1							
	28–25.0	267.1	14– 0.2									
	29–20.0		16– 9.8									
	30–13.5		21–17.0									
	241.0		26– 1.0									
			173.0									

TABLE 3. General parameters of 50 harvests in 1978 (average of 5 replications)

Description	IAC52/326				CB41–76				CB44–52			
	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20
Furrow meter/Ha	6,667	5,555	5,000	4,454	6,667	5,555	5,000	4,545	6,667	5,555	5,000	4,545
T.C.H.	54.04	63.26	63.33	73.64	69.24	75.70	72.27	74.55	60.71	62.81	66.00	65.76
Column/Ha	76,693	74,400	78,080	81,855	76,427	71,289	74,000	69,745	58,987	56,662	55.760	54,836
Column/m Furrow	11.5	13.4	15.6	18.0	11.5	12.8	14.8	15.3	8.8	10.2	11.2	12.1
Weight/Column (kg)	0.70	0.85	0.81	0.90	0.91	1.06	0.98	1.07	1.03	1.03	1.11	1.20

TABLE 4. Tonnages p/hectare production in 5 harvests, (average of 5 replications)

Harvests	IAC52/326				CB41–76				CB44–52			
	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20
1974	67.24	64.67	58.43	72.15	65.64	68.92	65.07	63.40	61.51	58.89	57.60	54.67
1975	79.13	74.13	73.16	96.25	76.05	75.95	74.36	81.91	72.65	69.91	72.90	73.27
1976	71.91	73.88	76.07	82.34	85.78	86.96	83.95	80.62	77.63	77.67	81.36	71.22
1977	65.33	75.92	73.87	83.76	77.15	79.85	75.20	80.30	67.20	71.56	72.20	72.12
1978	54.04	63.26	63.33	73.64	69.24	75.70	72.27	74.55	60.71	62.81	66.00	65.76
Total	337.65	351.86	344.86	408.14	373.86	387.38	370.85	380.78	339.70	340.84	350.86	337.04
Averages	67.53	70.37	68.97	81.63	74.77	77.48	74.17	76.16	67.94	68.17	70.01	67.51
		DMS – 9.7				*DMS – 7.7*				*DMS – 7.1*		
		CV – 7.49				*CV – 5.60*				*CV – 5.71*		

TABLE 5. Number of Column per furrow linear meter.

	IAC 52/326				CB41–76				CB44–52			
Harvests	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20
1974	12.68	15.55	15.26	17.17	10.95	14.09	14.32	14.41	7.90	9.78	9.50	10.20
1975	12.34	16.57	17.15	19.35	12.29	15.35	16.35	16.29	9.16	11.71	12.44	12.95
1976	13.87	15.28	17.56	19.52	12.91	14.52	16.29	18.10	9.05	10.34	11.66	12.21
1977	11.24	12.83	13.70	15.52	11.16	12.85	13.70	15.08	8.08	9.30	10.79	13.13
1978	11.50	13.39	15.62	18.01	11.46	12.83	14.80	15.34	8.85	10.19	11.15	12.06
Total	61.63	73.62	79.29	89.57	58.77	69.64	75.46	79.22	43.04	51.32	55.54	60.55
Averages	12.32	14.72	15.85	17.91	11.75	13.92	15.09	15.84	8.60	10.26	11.10	12.11
		DMS – 1.0				*PMS – 0.8*				*DMS – 0.6*		
		CV – 3.67				*CV – 6.27*				*CV – 3.28*		

TABLE 6. Averages of colm population per hectare and weight per colm. in 5 harvests.

Description	IAC52/326				CB41-76				CB44-52			
	1.50	1.80	2.00	2.20	1.150	1.80	2.00	2.20	1.50	1.80	2.00	2.20
Colm/ha	82,190	81,700	79,296	81,421	78,367	77,377	75,462	72,025	57,395	57,045	55,547	55,051
Weight/colms (kg)	0.82	0.86	0.87	1.00	0.95	1.00	0.98	1.06	1.18	1.19	1.26	1.22

TABLE 7. Technological analyses.

	IAC 52/326				CB41-76				CB44-52			
Analyses	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20	1.50	1.80	2.00	2.20
BRIX	21.59	21.59	20.79	21.39	20.19	21.39	20.59	20.99	21.19	20.39	19.99	21.39
POL	20.10	19.94	19.18	19.93	18.52	19.40	18.98	19.11	19.76	18.28	17.87	19.88
PURITY	93.0	92.3	92.2	93.1	91.7	90.6	92.1	91.0	93.2	89.6	89.3	92.9

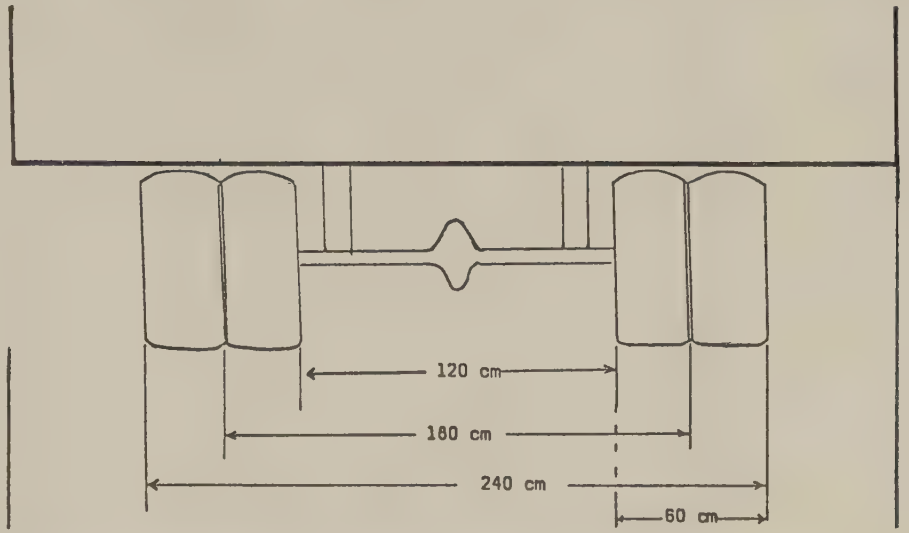

FIGURE 3. Measurement of rear wheels of a conventional transport vehicle

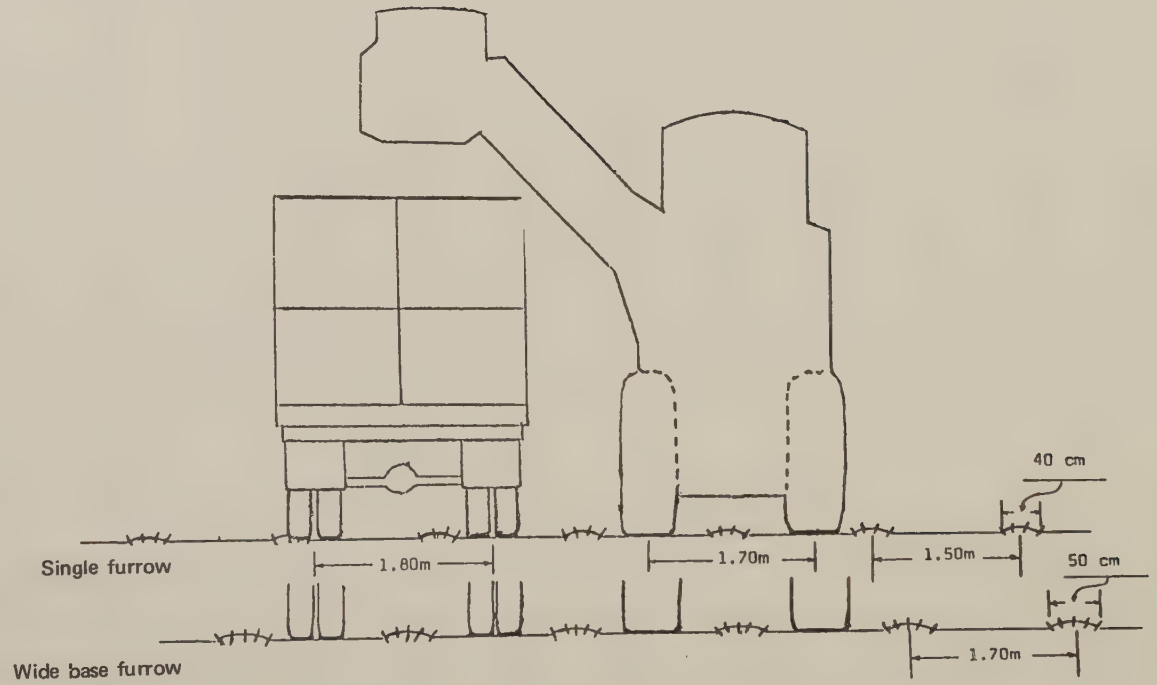

FIGURE 4. Schematic position of both transport vehicle and harvester of a planted sugarcane in common and wide base furrows, 4 ratoon stage

Correlating this phenomenon and amount of stalks in furrows, it can be deduced that confinement of sugarcane began after the 3rd harvest in narrower spacements. This probability confinement is more characterized in single furrows 1.50 m apart and more accentuated for IAC52/326 variety.

Considering the yields and respective distances in meters of furrow for different treatments, it will be possible to admit the preference for wide base 2.20 m planting. However, field observations indicate the 1.80 m spacing as the best option, with regards to closing in and weed control. This contradicts the expectation for row with greater dimensions containing ratoons in wide base planting since these were not more than 50-55 cm in the 5th harvest, compared with 35-40 cm for ratoon in conventional furrow of 1.50 m spacing.

Operational Aspects

Fig. 3 shows the approximate measures for rear wheels of a conventional vehicle for sugarcane transport. Discrepancy between those dimensions and spacings of 1.50 m and 1.40 m, predominantly the latter, in sugarcane planted in Brazil, is evident.

Inevitably one of the sides of the vehicle passed on the ratoon row. Consequently the soil compaction was greatly responsible for progressive reductions of the yields in successive harvests. In the case of agricultural transports, whose wheels are between 1.60 m and 1.70 m apart, the planting in spacings from 1.40 m to 1.50 m allows their passage in sugarcane interlines. For the transport vehicles, the coincidence will only occur if sugarcane was planted from 1.70 m to 1.80 m spacing. Fig. 4 presents a harvester and a transport vehicle whose wheel projections show its localization over 1.40 m and 1.70 m spacings.

Since the planting in wide base combines both field operational conditions, though losing in yield for single furrows, the sugarcane culture has an extra optional practice to study. A 50 cm wide sugarcane row will not be damaged by vehicle wheel because free space is approximately 1.20 m open. Thus, eventual effect of soil compaction close to sugarcane lines will be solved with cultural operations of ratoons, using subsoiler implements.

CONCLUSIONS

Wide base furrows with 1.80 m, 2.00 m and 2.20 m spacings in 5 successive harvests under the used methodology, resulted in similar productions, compared with traditional planting in single furrows of 1.50 m distance. Spacings larger than 1.80 m with wide base, despite shorter distances in meters of furrows per area, were not recommended due to problems with later shutting of the culture. Spacings with 1.80 m and 1.70 m for wide base furrows adequate to the gauge of machines and transport vehicles, permit the traffic into the area being cultivated, using only the sugarcane interline.

The deep applications of fertilizer or only the use of subsoiler implements

in both sides of the ratoon rows, will avoid the eventual soil compactions in those locals. Soil decompaction in the interline will not be affected, the density retaining bulk by the traffic of machine and vehicles during consecutive harvests. Consequently the planting in wide base furrows, of 1.70 m and 1.80 m spacings constitute an option to the traffic control into sugarcane area.

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SUCROSE DE BASE ANCHA PARA SIEMBRA DE CAÑA CINCO PRODUCCIONES DE COSECHA

J. Fernandes, V. L. Furlani Neto, D. Camposilvan y R. Stolf

RESUMEN

La siembra de 3 variedades de caña de azucar en surcos de base ancha con aperturas internas de 30 cm y espaciados a 1.80 m, 2.00 m y 2.20 m mostró aumento en redimiento durante 5 años consecutivos, comparados con surcos convencionales con distancias de 1.50 m. Por otro lado, surcos a 1.70 m y 1.80 m de distancia, que coincidian con medidas de distancia entre ruedas de vehiculos de transporte de caña, le permiten transistar usando unicamente surcos alternos, sin ocasionar daños a los retoños por compactaction de suelos. Consecuentemente la siembra de caña de azucar en surcos de base ancha será adecuada para el control de transito de vehiculos de transporte en el area cultivada.

MECHANIZATION OF HIGH POPULATION SUGARCANE IN LOUISIANA

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ABSTRACT

Cultural practices and production system using commercial varieties of sugarcane and more efficient utilization of sunlight per unit area of the conventional 180 m row have increased the yield of sugar per hectare in Louisiana. Field mechanization from seedbed preparation through harvesting was developed to correspond to the non-conventional production system. A parabolic subsoiler was modified to provide a greater soil fracture area with less power than the conventional straight shank subsoiler. A wide furrow opener was developed to provide a furrow with a profile specified by an agronomist for optimum development to cover wide furrow planted sugarcane. Hydraulic motors connected in series provided power to modified chopper disk gangs. Adjustments were provided to vary the speed of rotation, soil lifting effect and width of cut of the disk. The conventional single bottom cutting blade for a soldier type harvester has an effective cutting width of 60 cm. The single blade was removed and a double blade cutting system was developed. The double blade system was capable of efficiently harvesting cane 120 cm wide.

INTRODUCTION

References are made to high population sugarcane as double drill, multiple drill, narrow row or wide furrow methods of planting. Each type of planting is an effort to increase sugar production per hectare. Louisiana State University and USDA research agronomists have experimented with various combinations of drills and row widths to produce higher yields using commercial varieties. These experiments were designed to utilize more of the sunlight per unit of growing area. Several types of planting using various cultural methods have been studied to increase the yield and positive results were obtained (Ricaud[3]). However the type of planting or cultural practice must be integrated into a production system. Field mechanization from seedbed preparation through harvesting must be coordinated and adapted into the production system (Cochran[1]). The development or modifi-

cation of four mechanical implements needed to mechanize the production of high population sugarcane in Louisiana will be discussed in this presentation.

MODIFIED PARABOLIC SUBSOILER

Soil compaction is a serious problem on sandy soils in the Louisiana sugarcane area. This is due mainly to the use of heavy field equipment during wet conditions and to the lack of effective subsoiling. The type of subsoiler used extensively in Louisiana consists of a straight 4 cm shank that opens a narrow furrow approximately 6 cm in width and requires considerable power to pull through the soil (Ricaud[3]). Researches have found that shanks narrower than 5 cm tend to slice through the soil rather than fracture and lift it.

Tupper[5] designed a parabolic shaped subsoiler for use in cotton which lifted and fractured the soil and required less power than straight shank subsoilers. The parabolic subsoiler was designed as a parabolic curve with a gradual increase in slope from 22° at the foot to 55° at the soil surface when operating at a 40 cm depth. In most cases under similar conditions the parabolic subsoiler can be pulled by a tractor using at least one higher gear than is needed for a conventional subsoiler that does not fracture the soil as well.

Wide furrow and multiple drills are planted over a wider area of the row sur-

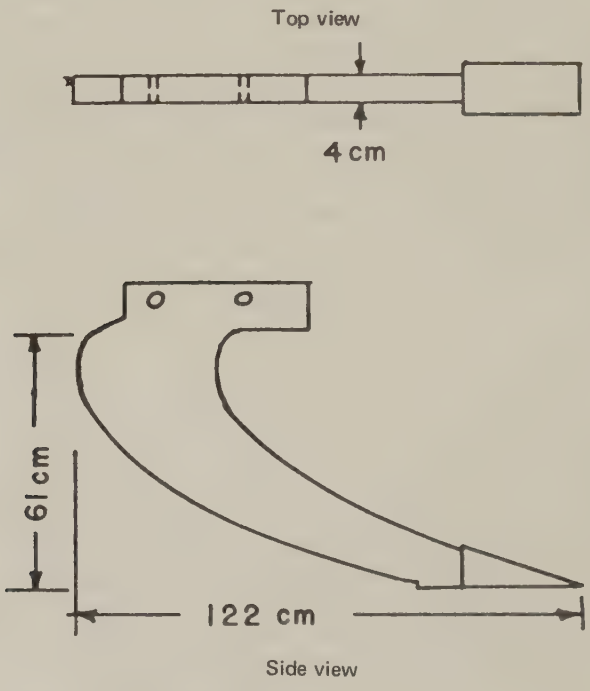


FIGURE 1a. Standard parabolic subsoiler

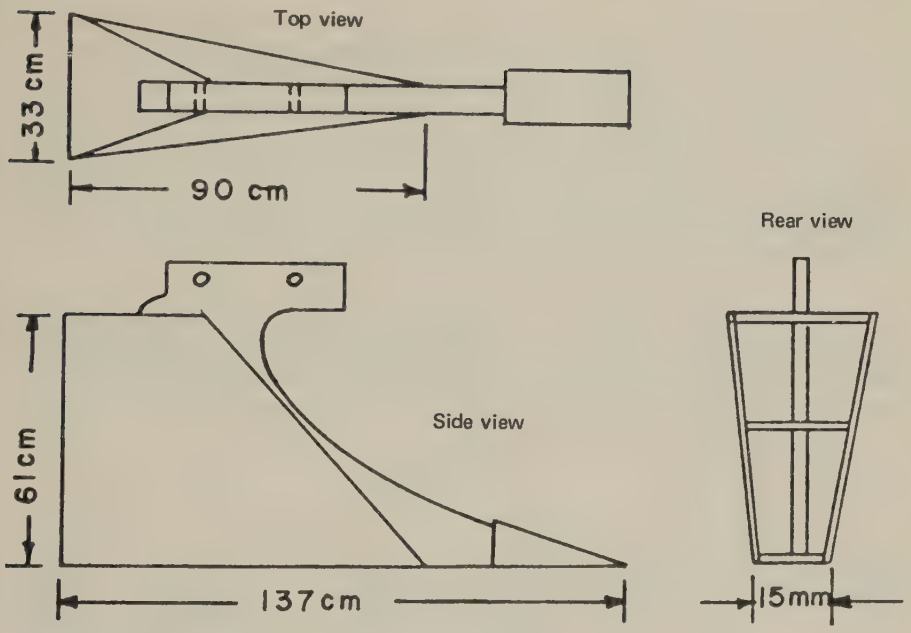


FIGURE 1b. Modified parabolic subsoiler

face, therefore the width of the soil fracture area during subsoiling should be increased to obtain the maximum effects of the subsoiling operation.

The parabolic subsoiler was modified to provide a greater area of soil fracture. Wings were attached to the parabolic shank as shown in Fig. 1. The wings were constructed from sheet iron 1 cm thick and extended to a height of 61 cm from the bottom of the shank. Each wing was tapered away from the shank to provide a maximum spacing of 33 cm between the top of the wings and a minimum spacing of 15.2 cm at the bottom.

The modified parabolic subsoiler required more power to pull through the soil than the conventional parabolic shank but less than the conventional straight shank. Penetrometer readings showed that the fracture of the soil surface with the modified parabolic measured 1143 mm perpendicular to the direction of travel. The standard parabolic and standard vertical subsoilers measured 762 mm and 406 mm respectively (Haji-Jaafar[2]).

FURROW OPENER

One of the major problems encountered when planting cane in wide furrows was to keep the seed pieces spread to the outside edges of the furrow. In developing a wide furrow opener the design included a provision to open a furrow shaped with indentations along the outside edges. The wide furrow profile shown in Fig. 2 is desirable to assist in keeping the seed cane distributed across the furrow.

The implement for opening wide furrows was developed by modifying a commercial lister type plow. Parts of the wings on a 35 cm lister plow were removed and larger wings were attached to the plow share shown in Fig. 3 to provide the width of furrow desired. Each wing was positioned at a horizontal angle of 22° with respect to the center line of travel and the wing length was equal to the width of the desired furrow. Experimental results showed that the furrow opener should have a wing spread at the rear of the plow equivalent to 15 cm wider than the width of the furrow to be opened. The additional width was added to allow for soil falling back into the furrow after the opener has passed.

The desired furrow profile was obtained by making the rear of the wing a minimum of 7.5 cm lower than the bottom of the plow share. This dimension provided a deeper furrow on the outer edges to assist in keeping seed pieces on the outside extremities of the furrow during planting and covering.

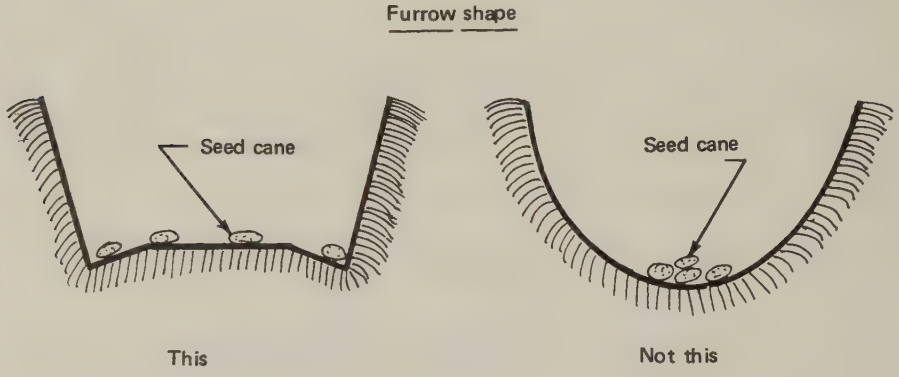


FIGURE 2. Profile of wide furrow for high population sugarcane.

Each wing had a curved shape to roll the furrowed soil away from the plow. There was no curvature where the wing was attached to the original lister plow. The portion of the wing that was curved increased from zero to a maximum of ½ the wing height at the rear. Lateral braces 20 mm in diameter were connected to the plow shank and the wings to stabilize the vertical movement of the plow during operation. Cross braces were used to support lateral forces on the wings.

POWDERED COVERING DISK

Proper covering of wide furrow planted cane is important. Seed cane must remain distributed across the entire width for wide furrow planting to be effective. Furrows up to 45 cm wide can be effectively covered using standard chopper disks. To cover cane planted in furrows greater than 45 cm, including 90 cm and 120 cm width, a powered disk implement was developed. The powered disks, shown in Fig. 4, lifted and moved the covering soil over the seed cane without forcing the seed pieces together.

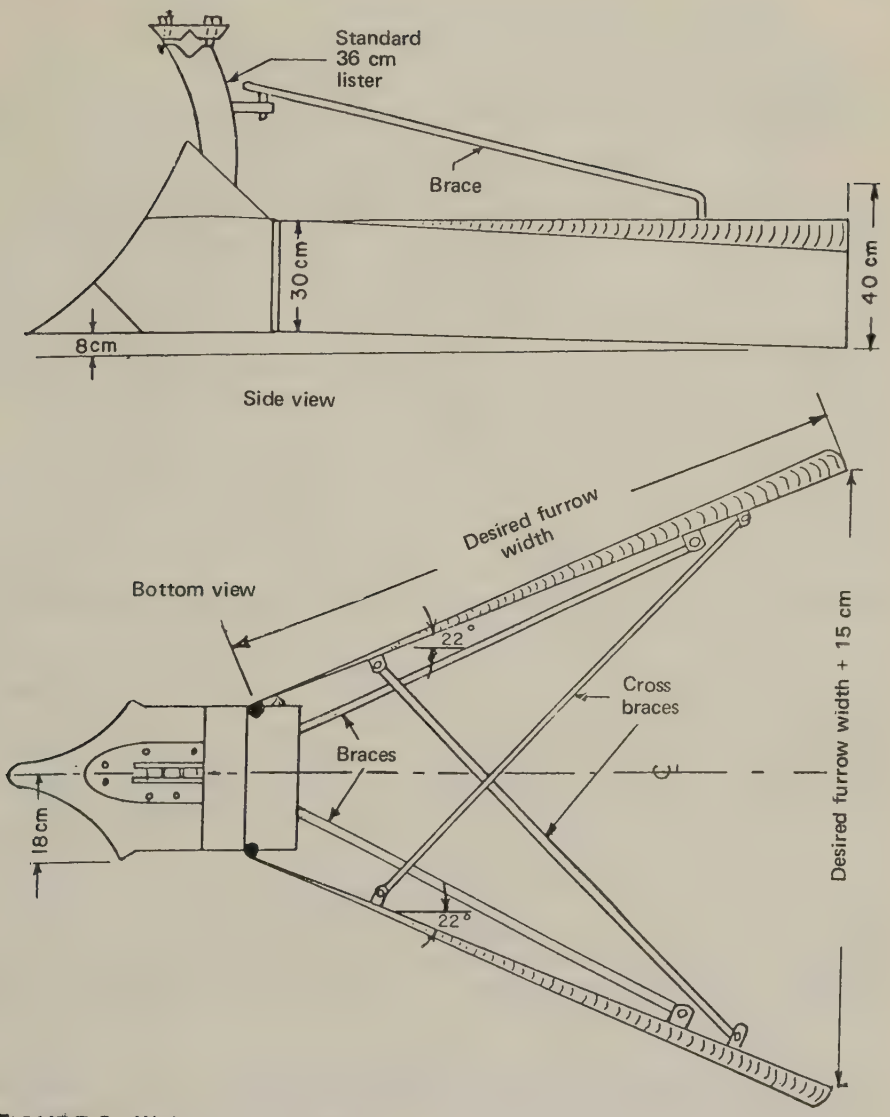


FIGURE 3. Wide furrow opener

Development of the powered disks began with two commercial chopper disk gangs with 3-60 cm blades. The outside disk on each gang was removed. A hydraulic motor was mounted and attached to the shaft positioned through the remaining two disk blades. Hydraulic motors were selected to rotate the two disks at a speed of 175 rpm. The two hydraulic motors were connected in series as shown in Fig. 5 to maintain a constant speed of rotation for each disk gang. A minimum flow rate of 40 liters per minute through the circuit with an operating pressure of 2200 psi available is recommended to power the disks. The hydraulic circuit may be attached directly to the tractor remote hydraulic system provided the tractor

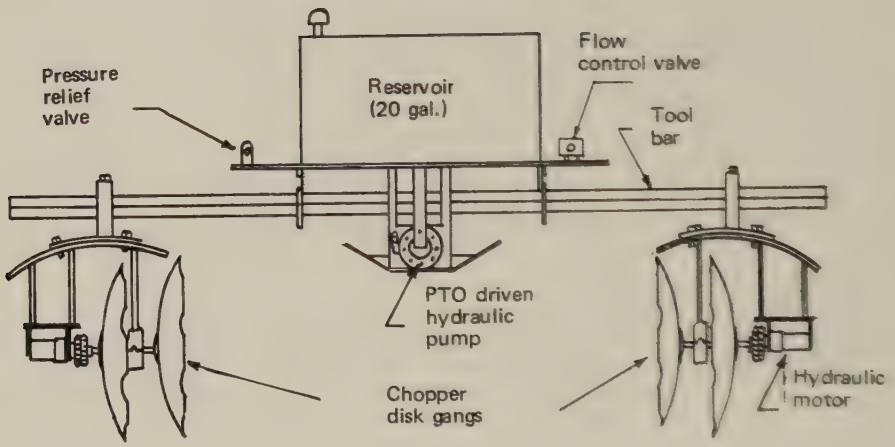


FIGURE 4. Schematic drawing of powered disk developed to cover sugarcane planted in wide furrows.

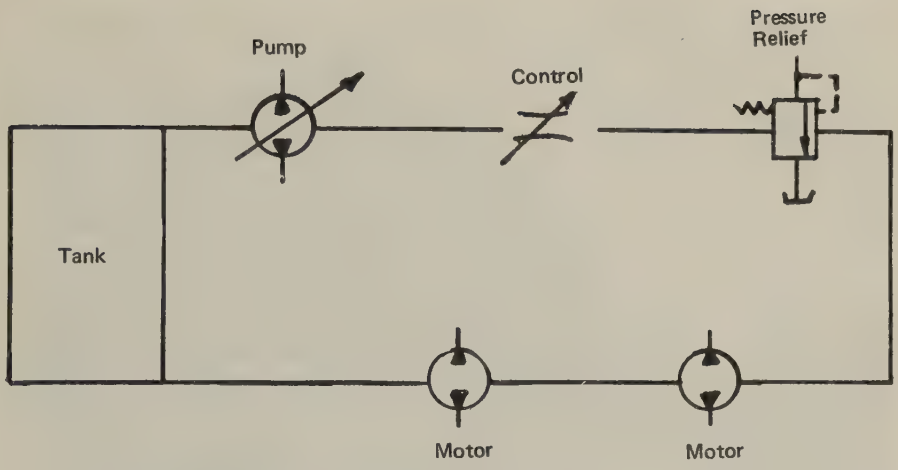
hydraulics can supply an adequate flow rate and pressure to operate the implement continuously. An independent hydraulic system was designed and mounted on the implement tool bar. A positive displacement piston pump was driven by the tractor power take off. Pressure relief and pressure compensated flow control valves were included in the circuit to protect the pump and regulate the disk rotating speed.

The chopper disk frame had adjustments so the vertical angle of the disk could be changed to vary the lifting effect of the disks. Adjustments in the horizontal angle could be made to change the width of the soil slice of the disk. Forward tractor speed also affected the amount and position of the soil moved by the disk. Combinations of the adjustment built into the implement provided adequate covering soil for cane planted in furrow widths up to 180 cm.

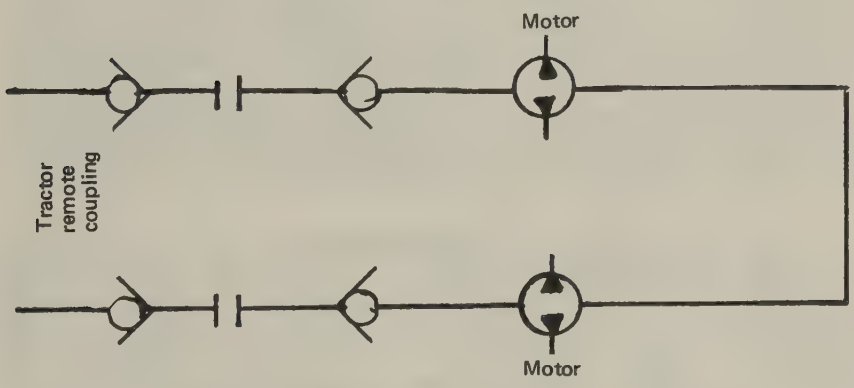
MODIFIED SOLDIER TYPE HARVESTER

Producing sugarcane from wide furrows requires cultural practices that maintain a flat row surface profile so maximum harvesting efficiency can be obtained. Producing high yields of sugarcane is not significant unless the crop can be harvested and delivered to the mill efficiently and economically. Louisiana has an efficient harvesting operation for cane produced on conventional drills and a large capital investment would be required to change from the soldier type harvesting system.

Research was directed toward modifying the conventional soldier type



A. Independent hydraulic circuit



B. Tractor connected hydraulic circuit

FIGURE 5. Hydraulic circuits for powered disk implement

harvester to harvest cane produced on wide beds. Results have shown that a single, 90 cm diameter bottom blade for a soldier harvester has an effective cutting width up to 60 cm. Harvesting cane wider than 60 cm with a single bottom blade leaves cane in the field and reduces harvesting efficiency. A double blade system for a soldier type harvester was developed by Cane Machinery Engineering Company and the LSU Agricultural Engineering Department to harvest cane wider than 60 cm including the maximum width that can be effectively produced on a 180 cm row. The double blades shown in Fig. 6 were 75 cm in diameter and positioned with one blade forward of the second blade to provide a 7.5 cm overlap of the inner cutting edges. The blades were powered hydraulically and connected in a series circuit. Additional hydraulic power was used to provide each blade with approximately the same power as a single bottom blade system.

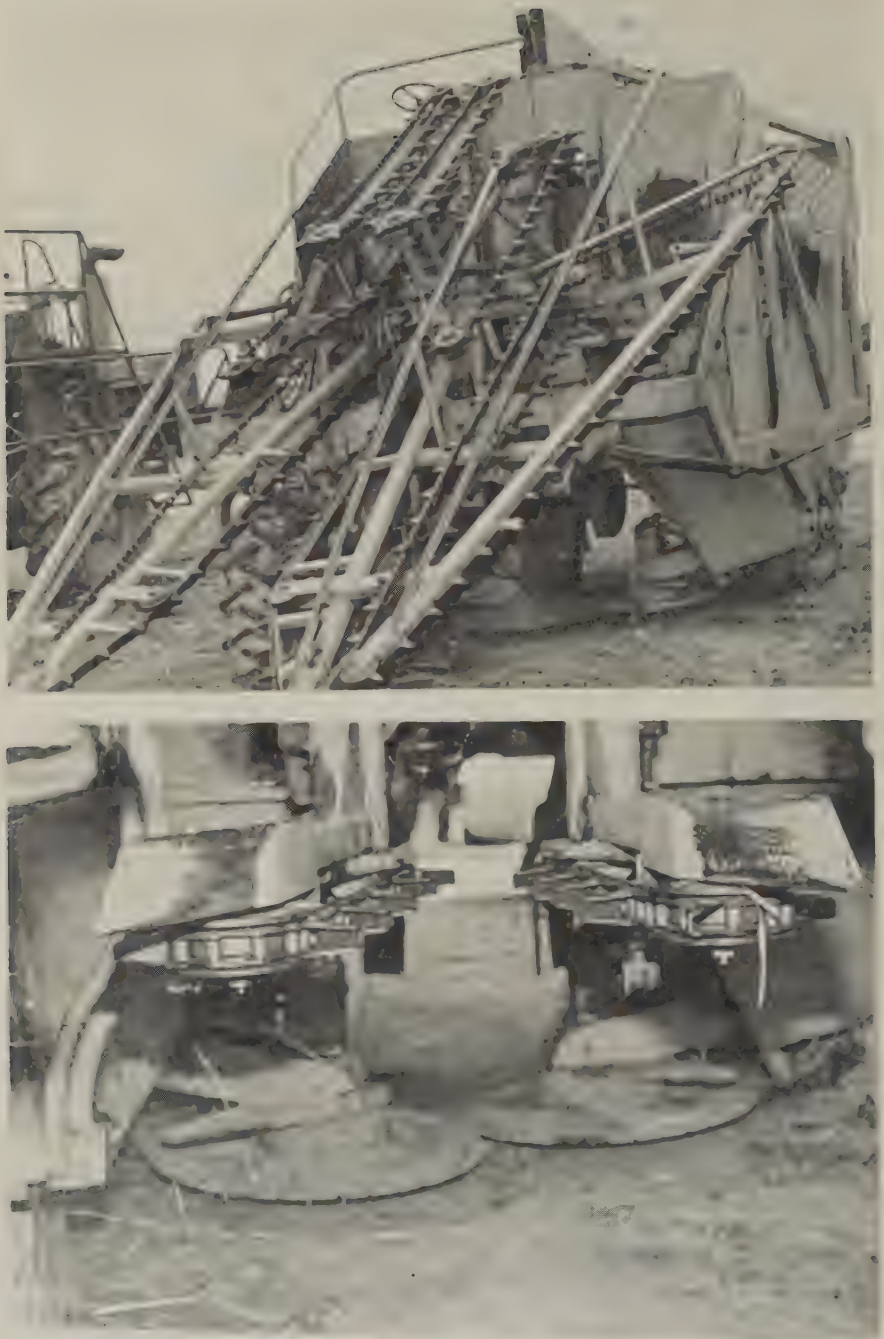


FIGURE 6. Soldier type harvester modified with double bottom blades for harvesting sugarcane produced on wide beds.

The double blade operated simultaneously and could be raised or lowered to the same level without contacting each other. The cutting blades rotated in opposite directions inward which caused a sweeping action to move and orient the stalks toward the center of the harvester in line with the sticker carrier chain. Single blade soldier harvester can be modified with double bottom cutting blades but this modification should be done by experienced manufacturers.

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MECANIZACION DE LA ALTA POPULACION DE CAÑA DE AZUCAR EN LOUISIANA

B. J. Cochran & R. Ricaud

RESUMEN

Los modos culturales y el sistema de producción usando variadades comerciales de la caña de azúcar y mas eficiente utilización de la luz del sol cada unidad de area de la linea convencional 180 m han aumentado el rendimiento del azúcar por hectarea en Louisiana. Mecanización del campo desde la preparación de la semilla por medio de cosechar fue desarrollado para corresponder al sistema no convencional de la producción.

EFFECTS OF HARVEST TRAFFIC AND SOIL WATER CONTENT ON SOIL COMPACTION AND REGROWTH OF SUGAR CANE

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ABSTRACT

The effects of manual and mechanical harvesting traffic on Mc Bean fine sandy loam soil were studied. The soil bulk densities were high before harvesting and were increased to 1.62 g/cm^3 and 1.66 g/cm^3 after manual and mechanical harvesting, respectively. Both harvesting methods caused reductions in soil macroporosity and increases in penetration resistance. Mechanical harvesting reduced the depth to maximum compaction to a significantly greater extent than manual harvesting (62% and 29%, respectively).

Compaction as a result of mechanical harvesting traffic was also studied on three other soils (Cunupia clay, Frederick clay and Talparo clay) at three soil moisture levels. Traffic at increasing soil water contents caused significant bulk density increases of 9% to 12%. The final bulk density of the Cunupia clay was 1.54 g/cm^3, and the other soils had lower densities. However, no definite relationship was observed between soil moisture level and the other physical properties since the effects were evident at the lowest soil moisture level.

Both harvest traffic and soil moisture level affected cane regrowth. Cane heights four months after mechanical harvesting were 20% shorter at harvest time, but no difference was observed in the root distributions after manual and mechanical harvesting. Increasing soil moisture levels during mechanical harvesting greatly reduced root distribution on the Cunupia and Talparo soils and reduced cane height by 18% to 27% at the highest soil moisture levels. The effects on cane height were, however, less pronounced when the canes were mature.

INTRODUCTION

During sugarcane harvesting operations, machinery traffic imparts a great comparative effort to the soil. The extent of the resulting compaction in a soil

series depends on the number of wheel passes, the magnitude of the applied pressure and the soil water content. The number of wheel passes is constant for any harvesting system and may be one pass in a manual system or up to 12 passes in some mechanical systems. The magnitude of the applied pressure is determined mainly by the cane haulage unit and it increases during the operation as the vehicle fills while being loaded with cane. Soil water content is usually low at the time of harvest and under these conditions the soil can be generally expected to withstand a compactive effort with minimum compaction. However, the major soils on which sugarcane is grown in Trinidad can be compacted to high densities even when relatively dry and mechanical harvesting traffic was reported to cause significant bulk density increases in 3 soils (Georges[1,2]). Furthermore, there is occasionally sufficient rainfall in the dry season to raise the soil water content to a high level to permit severe compaction during the harvest.

Soil compaction increases bulk density, reduces macroporosity and increases penetration resistance of the soil thereby causing reduction in the cane height and root distribution (Trouse and Baver[5], Trouse and Humbert[6]) and reduced uptake to nutrients, especially P (Juang and Uehara[4]). Furthermore, repeated harvesting of subsequent ratoons under wet soil conditions may cause further soil compaction (Trouse and Baver[5], Trouse and Humbert[6], Yang[7]).

The studies reported in this paper sought to measure these effects of harvest traffic on sugarcane grown in Trinidad in order to identify situations of severe soil compaction on 4 soil series.

MATERIALS AND METHODS

The following 4 soils were studied: Cunupia clay, Frederick clay, Mc Bean fine sandy loam and Talparo clay. Data on the particle size distribution, texture, bulk density, porosity and penetrating resistance of the soils before harvest are given in Table 1.

In order to study the effects of normal harvest traffic on the soils, the fields were burnt and harvested normally without altering the load or the number of passes. Details of the vehicles and loads used for manual and mechanical harvesting operations in the experiments are shown in Table 2. No subsoiling was done after harvesting the cane.

The effects of manual and mechanical harvesting systems were compared in an experiment on the Mc Bean fine sandy loam. The field was divided into 8 plots and the 2 harvesting systems were replicated 4 times. Three cane rows were randomly selected within each plot and 3 sampling sites were randomly selected within each of these rows. The following soil characters were measured in the furrow (inter-row) before and after harvest traffic: soil water content, bulk density, pore size distribution and soil penetration resistance.

TABLE 1. Physical properties of 4 soils before harvest traffic

Soil Series	Particle size distribution					Bulk density g/cm^3	Total porosity %	Macro-porosity %	Penetration resistance	
	Coarse sand %	Fine sand %	Silt %	Clay %	Texture				Maximum kg/cm^3	depth cm
Cunupia	04	18	30	47	C	1.38	51	4.6	28	12
Frederick	01	03	18	78	C	1.25	60	4.2	21	17
Mc Bean	19	48	16	17	FSL	1.56	47	2.4	23	9
Talparo	02	08	14	76	C	1.22	57	4.3	26	15

TABLE 2. Vehicles and loads used for manual and mechanical harvesting operations

Harvesting methods	Vehicles	Maximum payload of trailer t	Maximum Gross wt. (trailer & cane) t	Harvester wt. t	Number of wheel passes per furrow
Manual	Tractor and self-loading trailer	4	5	—	1
Mechanical	Cary Harvester tractor and tipping trailer	10	15	13	11
Mechanical	Class Harvester tractor and tipping trailer	5	8	11	12
Mechanical	MF 201 Harvester tractor and tipping trailer	10	15	9	12

In another experiment, the effects of mechanical harvesting at 3 soil water contents often found during the dry season were studied. The soil water content treatments were achieved by spraying the cane rows with water before harvesting, using a pressure hose. The rates of water applied were equivalent to 0 mm, 10 mm, and 20 mm of rainfall. This experiment was conducted on 3 soils: the Cunupia, Frederick and Taiparo series. A randomized block design was used with 4 replicates in each case. The experiments consisted on 12 plots on each soil with an area of 33 m^2 per plot. The same soil characters were measured in 2 sampling sites per plot before and after harvest traffic.

Soil water content was measured gravimetrically and expressed on a dry weight basis. Bulk density and pore size distribution measurements were made on undisturbed soil sampled in cores 5.85 cm long and 5.00 cm in diameter. A proctor penetrometer was used to measure maximum penetration resistance and the depth to maximum compaction. Soil compaction was expressed as percent change in the soil characters after harvest traffic. The use of percent change clarified the compactive effects by eliminating the pre-harvest effects of soil water content on the physical properties of the soil, especially bulk density and penetration resistance. Ratoon regrowth was studied by measuring cane heights and root distribution in the sampling sites. Root distribution was measured in the furrow by the core sampling and root extraction technique of Hardy[3].

RESULTS

Effects on soil compaction

Fig. 1 compares the effects of manual and mechanical harvest traffic on the soil physical properties of the Mc Bean fine sandy loam.

The bulk densities were high before harvest and were increased by only 4% and 7% as a result of manual and mechanical harvest to final densities of 1.62 g/cm^3 and 1.66 g/cm^3, respectively. These increases were associated with statistically significant reductions in macroporosity and smaller reductions in total porosity. Traffic by manual, and especially mechanical harvesting also adversely affected the soil penetration resistance to a significant degree ($p = 0.05$). The maximum penetration resistance values were high before harvest (22 to 24 kg/cm^2) and were further increased by 12% and 16% by manual and mechanical harvesting, respectively. The depth to maximum compaction was shallow before harvest (less than 10cm) and was further reduced by both harvesting methods, but mechanical harvesting caused a much greater reduction than manual harvesting (62% and 29%, respectively).

Table 3 shows the compactive effects of the mechanical harvesting systems used on the bulk density, porosity and penetration resistance of the 3 soils at 3 soil water contents.

Increases in soil water content at harvest caused bulk densities to increase. At

TABLE 3. Per cent changes in physical properties of 3 soils after mechanical harvest traffic at 3 soil moisture levels

Soil series	Water content		Per cent changes in soil physical properties				
	Level	%	Bulk density	Total porosity	Macro-porosity	Maximum penetration resistance	Depth to maximum compaction
Cunupia	1	14	+06	–04	–17*	+18*	–50*
	2	17	+10*	–04	–16*	+16*	–67*
	3	21	+12*	–04	–19*	+16*	–58*
Frederick	1	17	+04	–05	–23*	+24*	–35*
	2	20	+08	–08	–26*	+19	–47*
	3	24	+10*	–09	–26*	+15	–47*
Talparo	1	20	+04	–04	–10	+35*	–40*
	2	23	–08*	–04	–15*	+30*	–53*
	3	26	+09*	–05	–13*	+27*	–47*

**Value is significant at p = 0.05*

the lowest soil water content , the bulk densities of the soils were increased only slightly by harvest traffic, but the densities at the highest soil moisture levels were significantly increased on all the soils by 9% to 12%. The final bulk density of the Cunupia clay was 1.54 g/cm^3 while those of the Frederick clay and Talparo clay were 1.38 g/cm^3 and 1.33 g/cm^3, respectively.

The total porosity was reduced by 9% at the highest soil moisture level on the Frederick clay, but on the other soils the reduction did not exceed 5%. However, these reductions in total porosity were not significant at $p = 0.05$. On the other hand, macroporosity was greatly reduced by harvest traffic on all the soils even at the lowest soil water contents, and there was little further reduction as soil water content was increased. The Frederick clay had the greatest reduction in macroporosity (26%) after harvest traffic. The corresponding reduction in the Cunupia silty clay loam was 19% while the Talparo clay had a 15% reduction in macroporosity.

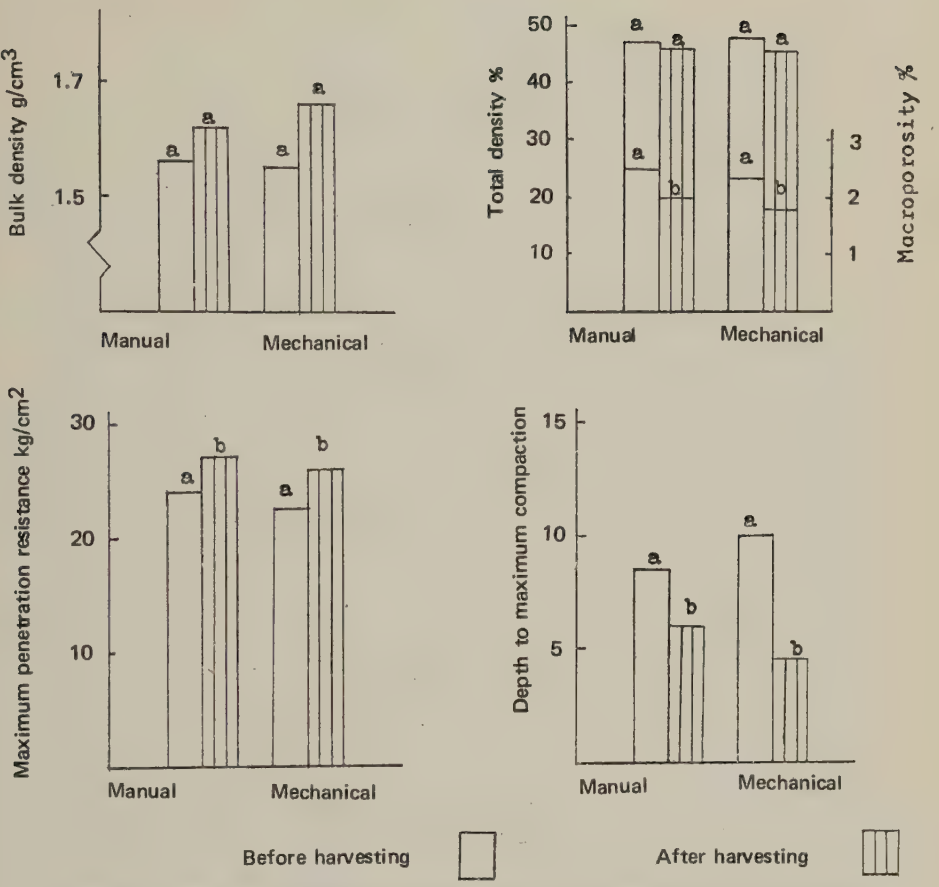
Harvest traffic increased the penetration resistance of the soils at every soil moisture level usually to a significant degree. However, because of the inverse relation between soil water content and penetration resistance, the final resistance values at the highest soil moisture levels were lower than the resistance values at the lower soil moisture levels. The depth to a maximum compaction was shallow and ranged from 12 cm in the Cunupia clay to 17 cm in the Frederick clay. After harvesting, this depth was reduced to within the range 4 cm (Cunupia series) to 9 cm (Frederick series) and the soil water content did not influence this depth.

Effects on regrowth

The effects of manual and mechanical harvesting on cane height and root distribution on the Mc Bean fine sandy loam after 4 to 10 months regrowth are shown in Table 4. Four months after mechanical harvesting the cane heights were 13% shorter than canes regrown after manual harvesting. Cane root distribution was poor and there was no difference observed as a result of the 2 harvesting methods. Final cane heights after mechanical harvesting was 20% lower than cane height after manual harvesting.

The effects of mechanical harvest traffic at the 3 soil moisture levels on cane height and root distribution on the Cunupia, Frederick and Talparo soils after 4 to 6 months regrowth are shown in Table 5. At this stage, cane heights after harvesting at the highest soil moisture levels were 25%, 18% and 27% shorter than those harvested at the lowest soil moisture levels on the Cunupia, Frederick and Talparo soils, respectively. Harvesting at the intermediate soil moisture level resulted in a much smaller reduction. Cane root distribution was adversely affected by increasing soil water content, especially on the Cunupia and Talparo soils in the top 15cm depth of soil.

These effects of soil moisture noted during early regrowth were however,



(Column in the same group not accompanied by the same letter are significantly different at p = 0.05)

FIGURE 1. Effects of manual and mechanical harvesting on soil physical properties of McBean fine sandy loam.

somewhat reduced by the time of the next harvest. Final heights indicated (Table 5) that at the time of the next harvest, the cane produced after harvesting at the highest soil moisture levels were 15%, 12% and 14% shorter than at the lowest soil moisture levels on the Cunupia, Frederick and Talparo soils, respectively.

DISCUSSION

The data indicate that the soil physical properties and sugar cane regrowth were adversely affected by the level of traffic during harvesting operations and by the soil moisture level. These trends were similar to those reported by Yang[7] for 2 soils in Taiwan where the resulting bulk densities were often high and within the range considered unsuitable for optimum sugarcane root growth according to Trouse and Humbert[6]. The Cunupia and Mc Bean soils were especially affected.

TABLE 4. Effects of manual and mechanical harvesting on cane height and root distribution on Mc Bean fine sandy loam

Harvesting system	Cane height * (cm)		Root distribution (mg/cm^3)			
	4 mths	11 mths	0–15 cm	15–30 cm	30–45 cm	45–60 cm
Manual	110	213	2.9	1.0	0.6	0.6
Mechanical	96	171	2.7	1.4	0.5	0.6

**Cane heights for manual and mechanical harvesting are significantly different ($p = 0.05$) at 4 months and 11 months regrowth*

TABLE 5. Effects of mechanical harvesting at 3 soil moisture levels on cane height and root distribution on 3 soils

Soil series	Soil water content %	Cane height * (cm) 4 mths	Cane height * (cm) 11 mths	Root distribution (mg/cm^3) 0–15 cm	15–30 cm	30–45 cm	45–60 cm
Cunupia	14	130a	263a	4.3	2.2	0.6	0.4
	17	117b	238b	3.1	1.9	0.9	0.6
	21	98c	224b	2.6	1.6	0.8	0.2
Frederick	17	116a	257a	3.8	2.1	1.4	1.2
	20	109a	235ab	3.5	2.0	1.5	1.0
	24	95b	226b	3.1	1.6	1.0	1.0
Talparo	20	112a	246a	3.4	1.3	1.1	1.0
	23	102ab	233a	2.5	1.4	0.4	0.6
	26	93b	212b	2.0	1.1	0.6	0.6

Cane heights in the same group not accompanied by the same letter are significantly different at p = 0.05.

The simultaneous reduction in macroporosity and increase in penetration resistance reduced the soil aeration and increased root impedance thereby causing the reduction in root activity and cane growth observed.

Mechanical harvesting under conditions of high soil moisture levels should be avoided. Since this is not always possible, the extent of the traffic may be reduced by transporting a smaller payload in the field or by adjusting tyre dimensions and inflation pressures. On the soils most prone to compaction, decompaction measures can also be taken, e.g., inter-row chiselling after harvest.

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EFFECTOS DE TRANSITO DURANTE COSECHA Y CONTENIDO DE AGUA EN COMPACTACION DE TERRENO Y RETOÑOS DE CAÑA DE AZUCAR

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RESUMEN

Se estudiaron los efectos de trafico de cosecha manual y mecanica en terrenos McBean arenosos. Las densidades del terreno eran altas antes de la cosecha y aumentaron a 1.62 g/cm^3 y 1.66 g/cm^3 despues de cosecha manual y mecanica respectivamente. Ambos metodos de cosecha ocasionaron reducciones en macroporosidad del terreno y aumentos en resistencia de penetracion. La cosecha mecanica redujo la profundidad maxima de compactacion a un grado significativamente mayor que la cosecha manual (62% y 29% respectivamente).

Tambien se estudio compactacion a tres niveles de humedad, como resultado de trafico de cosecha mecanica en otros tres tipos de terrenos (Cunupia arcilloso, Frederick arcilloso y Talparo arcilloso).

A media que el grado de humedad aumentaba, el trafico ocasiono aumentos significativos de densidad de 9% a 12%. La densidad final en terreno Cunupia arcilloso fue 1.54 g/cm^3 y los otros terrenos tuvieron densidades menores. Sin embargo, no se observo relacion definida entre nivel de humedad del terreno y otras propriedades fisicas ya que los efectos fueron evidentes al nivel mas bajo de humedad.

El trafico de cosecha y el nivel de humedad del terreno afectaron el crecimiento de retoños. Cuatro meses despues de cosecha mecanica el altura de la caña fue 20% mas corta, pero despues de cosecha manual o mecanica no se observo ninguna diferencia en la distribucion de raices.

El aumento en niveles de humedad del terreno durante cosecha mecanica redujo grandemente la distribucion de raices en los terrenos Cunupia y Talparo y redujo la altura de la caña entre 18% y 27% en los niveles mas altos de humedad de terreno. Sin embargo, los efectos en altura de caña fueron menos pronunciados en caña madura.